Preliminary Design Report

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# ORGANIC CHEMICAL TREATMENT FACILITIES AT AFFECTED BOROUGH WELLS

## Borough of Fair Lawn
## New Jersey

**November 1982**

**Project: 077-01-1100**

MALCOLM PIRNIE ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

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ENVIRONMENTAL ENGINEERS, SCIENTISTS & PLANNERS

BOROUGH OF FAIR LAWN
NEW JERSEY

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# PRELIMINARY DESIGN REPORT

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## ORGANIC CHEMICAL TREATMENT FACILITIES AT AFFECTED BOROUGH WELLS

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NOVEMBER 1982

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BOROUGH OF FAIR LAWN
NEW JERSEY

PRELIMINARY DESIGN REPORT

ORGANIC CHEMICAL
TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

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# 1. INTRODUCTION

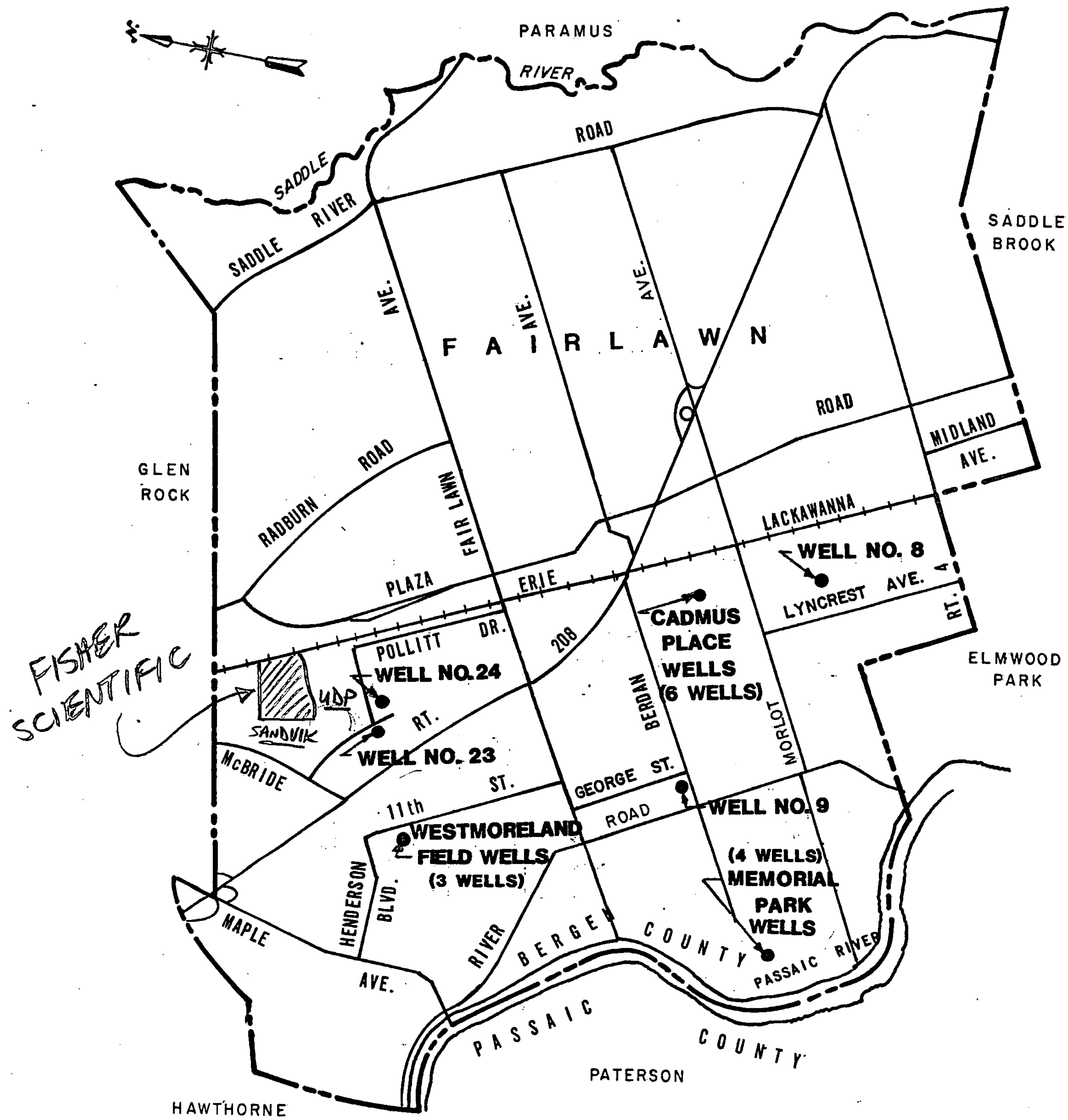
## Background

The Borough of Fair Lawn, New Jersey (Borough) operates a water supply and distribution system for potable and industrial use. The water supply system currently serves approximately 32,500 persons.

Water for the supply system is obtained from 17 Borough-owned wells and bulk-water purchases from the Hackensack Water Company and the Passaic Valley Water Commission. The location of the Borough's wells are shown on Figure 1. The distribution system consists of a network of piping ranging in size from small service connections to mains 20 inches in diameter. Two elevated tanks (300,000-gallon capacity and 1,000,000-gallon capacity) and two ground level tanks (1,500,000-gallon capacity and 1,100,000-gallon capacity) provide water distribution system storage. Raw water is disinfected with gaseous chlorine prior to distribution.

In 1978, various volatile organic compounds (VOCs) were detected in several Borough wells. Reports that VOCs, even in low concentrations, are potentially harmful to human health have caused a growing concern over their presence in water supplies throughout the country. Currently, the U. S. Environmental Protection Agency (EPA) is considering setting maximum contaminant levels (MCLs) for VOCs in drinking water. On March 5, 1982, the EPA issued an Advance Notice of Proposed Rulemaking concerning VOCs in order to initiate dialogue on potential regulations and to obtain additional information regarding the important aspects of the problem. Based on presently understood schedules, regulations will probably not be proposed until at least 1983.

In the absence of federal regulations, the New Jersey State Department of Environmental Protection (NJDEP) is

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS
LOCATION OF WELLS

utilizing a maximum level of 100 ug/l for total VOCs in the state's drinking waters. If total VOC levels in a water supply exceed this concentration, NJDEP will determine whether the water supply should be taken out of service considering its size and importance in relation to the remainder of a municipality's water supply.

In accordance with the above guidelines, the Borough has taken several wells out of service because these wells exceed the recommended maximum levels. Wells with low or trace levels of VOCs, plus additional purchases from outside sources, are being used to supply potable water for the Borough.

## Purpose and Scope

As a result of the VOCs being detected in the Borough's wells and the concern over these chemicals, the Borough retained Malcolm Pirnie to perform a treatability study of the Borough's affected wells to determine the most feasible strategy of providing water of acceptable quality. The purpose of this study is to evaluate, through treatability testing, alternative VOC treatment techniques and to develop criteria and preliminary layouts for designing full-scale treatment facilities at the affected wells. It is anticipated that this study will serve as an implementation plan for complying with the current guidelines of EPA and the NJDEP, and with potential future federal regulations.

The scope of work for this study includes:

1. Obtain, review, and evaluate available existing information concerning the capacity and operation of the Borough ground water supply system.

2. Obtain, review, and evaluate existing water quality data concerning the contamination of the Borough ground water supply.

3. Develop a testing program to evaluate alternative treatment methods (aeration and GAC adsorption)

for removing organic contaminants from Borough Well Nos. 2, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15, 16, 17, 19, 23, and 24.

4. Conduct treatability tests at the Westmoreland Well Field, the Cadmus Place Well Field, Well No. 9 and Well No. 24 to evaluate removal efficiencies and to develop design parameters.

5. Evaluate several treatment strategies, including separate treatment facilities and a central treatment facility, for cost effectiveness and select the most cost-effective strategy.

6. Prepare a report including a summary of the treatability testing and alternative analyses, preliminary designs and cost estimates of the selected treatment system, and a project schedule for implementing the selected plan.

Existing information relating to VOC levels which have been detected in the Borough's potable water wells and data concerning well capacities were obtained and evaluated to provide baseline information for identifying and evaluating alternative treatment methods and strategies.

DEMAND = 4.92 MGD

TOTAL CAPACITY = 2.64 MGD

PURCHASED = 2.38 MGD + .86 + ~~.52~~ = 3.~~76~~ 24 MGD

∴

2.64
− .86

TOTAL AVAL WELL CAPACITY = 1.78 MGD

## 2. EXISTING WATER SUPPLY SYSTEM

A review of the existing Borough water supply system was made to determine flowrates for each well which should be used in the design of VOC treatment facilities.

### Wells and Well Pumps

As indicated in the previous chapter, the Borough water supply consists of 17 wells. The scope of this report includes Well Nos. 2, 3, 4, 5, 6, 7, 9, 10, 11, 14, 15, 16, 17, 19, 23, and 24. Well No. 8 was excluded from this study because the VOC levels in this well generally have been found to be very low (less than 10 ug/l) or not detectable. Also, based on a hydrogeological study conducted by Roy F. Weston, Inc., this well does not appear to lie within the path of the VOC plume, and therefore is not expected to exhibit high VOC levels in the future.

Information relating to current capacity, depth, and location of the wells included in this study is summarized in Table 1. The total current capacity of the Borough well supply including the wells which are off-line, is estimated from existing information to be about 2.64 million gallons per day (mgd). The total capacity of the wells which are off-line is estimated to be 0.86 mgd, of which about 0.52 mgd is off-line because of high VOC levels.

The total water demand of the Borough has averaged about 4.92 mgd based on a review of operating records from 1971 to the present. To meet this demand, all serviceable wells are operated continuously and additional water is purchased from the Hackensack Water Company and the Passaic Valley Water Commission. Prior to the discovery of VOCs in some of the Borough's wells, outside sources accounted for

TABLE 1

FAIR LAWN WELL DATA

| Well No. | Current Capacity (gpm)[1] | Depth (ft)[2] | Location[3] | Comments |
|---|---|---|---|---|
| **Cadmus Well Field:** | | | | |
| 1 | - | 500 | E of Burbank St. South of High School | Permanently sealed |
| 2 | 60 | 300 | SE corner of Romaine St. and Fairclough Pl. | On-line |
| 3 | 70 | 300 | NE corner of Bellair Ave. and 17th St. | On-line |
| 4 | 80 | 300 | SW corner of Cadmus Place and Romaine St. | On-line |
| 5 | 60[4] | 300 | N side of Bellair Ave. between 15th and 17th Sts. | Down for pump repairs |
| 6 | 40 | 500 | NE corner of Bellair Ave. and 15th St. | On-line |
| 7 | 115 | 458 | SE corner of Burbank St. and Norma Ave. | On-line |
| Subtotal | 425 gpm | | | |
| **Willow St. Field:** | | | | |
| 8 | 190 | 338 | NE corner of Lyncrest Ave. and Willow St. | On-line, not included in this study |
| **George St. Field:** | | | | |
| 9 | 115 | 408 | NW corner of George St. and Berdan Ave. | On-line |
| **Westmoreland Well Field:**[5] | | | | |
| 10 | - | 500 | SW corner of 11th St. and Henderson Blvd. | High VOC levels, off-line |
| 11 | - | 400 | NE corner of Chester St. Ontario Ave. | High VOC levels, off-line |
| 14 | - | 400 | SW corner of Oak and Westmoreland Ave. | High VOC levels, off-line |
| Subtotal | 150 gpm | | | |

TABLE 1

FAIR LAWN WELL DATA (Cont'd)

| Well No. | Current Capacity (gpm)[1] | Depth (ft)[2] | Location[3] | Comments |
|---|---|---|---|---|
| Memorial Park Field: | | | | |
| 15 | 180[4] | 402 | NE corner of Essex Pl., N end of St. | Down for pump repairs |
| 16 | 140 | 413 | N end of Arnot Pl. | On-line |
| 17 | 160 | 350 | N of Arnot and Bush Pl. | On-line |
| 19 | 260 | 400 | N end of Arnot Pl. | On-line |
| Subtotal | 740 gpm | | | |
| Kodak Well Field: | | | | |
| 23 | 100[4] | 275 | Pollitt Dr. Extension, behind Kodak Plant | High VOC levels, off-line, pump removed |
| 24 | 110[4] | 400 | Pollitt Dr. Extension, W. side of Oxford University Press | High VOC levels, off-line |
| Subtotal | 210 gpm | | | |
| Total All Wells | 1830 gpm | | | |

Notes:

1. Based on recent pumping records for 1981 and 1982.
2. Based on data received from Water Department records.
3. Location of wells and/or well fields are shown on Figure 1.
4. Based on pumping rate during most recent operation.
5. Individual pumping rates were not recorded for Westmoreland Wells.

50 percent of the Borough's supply. After removing affected wells from service, outside sources have accounted for about 70 percent of the Borough's supply.

The Cadmus Place Wells (Well Nos. 2, 3, 4, 5, 6, and 7) and the Memorial Park Wells (Well Nos. 15, 16, 17, and 19) pump water to the 1,100,000-gallon ground level storage tank at Cadmus Place. The water is then pumped by a 3,200 gpm booster station into the distribution system or into the 300,000-gallon elevated storage tank depending on demand. Well No. 9, located on George Street, pumps directly into the 16-inch diameter distribution main along Berdan Avenue. The Westmoreland Field Wells (Well Nos. 10, 11, and 14 ) pump water into the 1,500,000-gallon ground-level reservoir. The water is then pumped by a 2,500 gpm booster station into the distribution system. Well No. 24, located adjacent to Oxford University Press, pumps water to the Well No. 23 station, where it is chlorinated. The chlorinated water then flows into a 12-inch diameter distribution main along Pollitt Drive.

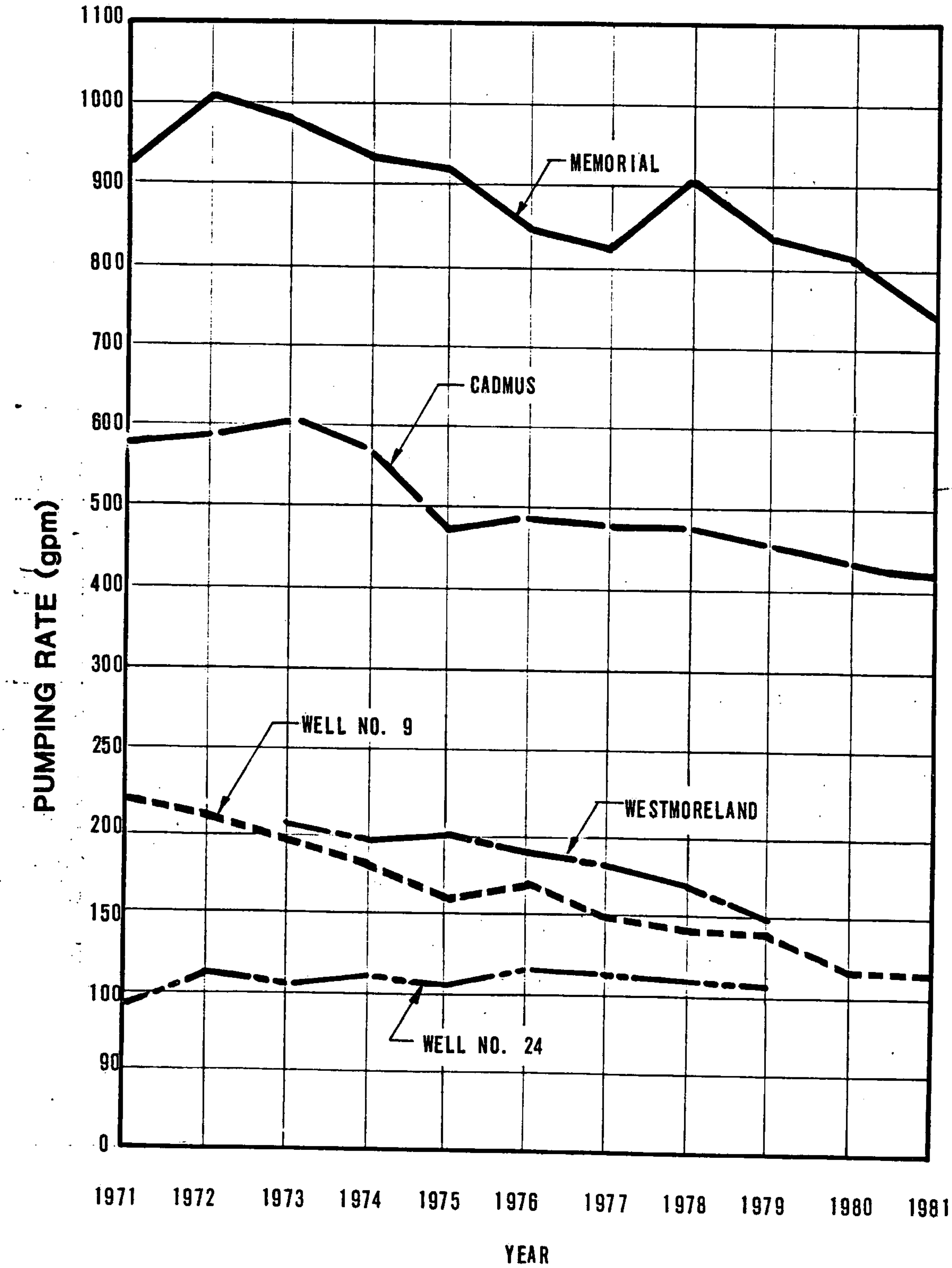
Under present operating conditions, Well Nos. 5 and 15 are out of service for repairs. The Westmoreland Field Wells are being pumped and the water discharged to Henderson Brook because of excessive VOC levels in these wells. Well No. 24 is also being pumped to waste because of high VOC concentrations. With the exception of Well No. 23, all of the other wells are in service and operated on a continuous basis. Well No. 23 currently is out of service because of pump repairs and high VOC levels.

## Design Flowrates for Treatment

Design flowrates for each well or group of wells were selected based on a review of historical pumping records and the results of other studies conducted for the Borough. For purposes of establishing design flowrates for treatment facilities, the current well pumping rates were compared to pumping rates recorded over the last decade. A comparison of these flowrates, shown on Figure 2, indicates that the pumping rates in most of the wells have decreased significantly over the past 10 years. The Memorial Well Field has lost about 20 percent of its pumping capacity. The Westmoreland and Cadmus wells have lost about 25 percent of their capacity. Well No. 9 has lost over 50 percent of its capacity. In contrast, Well No. 24 has pumped at a fairly steady rate over the past 10 years.

The decline in pumping rates over the past 10 years may be attributed to a combination of factors, including well inefficiencies (clogging of the well screen), pump inefficiencies (excessively worn parts) and reduced capacity of the aquifer because of continuous pumping over long periods of time. To determine the exact cause(s) of declining pumping rates in the Borough's wells would require an internal inspection of each of the wells. Pumping rates may be expected to be restored to 75-90 percent of original capacity through rehabilitation of the wells and/or well pumps. However, if the primary cause of declining pumping rates is reduced aquifer capacity, rehabilitation of the wells would help to restore only a portion of the pumping capacity.

Based on discussions with the Borough Engineering Department, it is understood that a well rehabilitation program is being planned for the Borough's wells. Depending on the causes of the declining pumping rates, it is anticipated that the well rehabilitation program will restore pumping rates in the Borough wells to levels near the original values. For purposes of selecting design flowrates for sizing treatment facilities, it has been assumed that pumping rates in the Borough wells will be restored to about 90 percent of their original capacity, which represents the maximum restoration which might be expected with well rehabilitation. Sizing a treatment facility on this basis will ensure that




MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

**HISTORICAL PUMPING RATES**

sufficient treatment capacity is available to treat the wells if rehabilitation results in maximum restoration of the pumping rates. The design flowrates for each of the wells are summarized in Table 2.

For purposes of estimating operating costs of treatment facilities, it is assumed that the wells will be operated continuously to provide the maximum quantity of water from the Borough's ground water system, thus minimizing the need to purchase water from outside sources. This mode of operation was confirmed through discussions with Water Department personnel.

TABLE 2

DESIGN FLOWRATES FOR FAIR LAWN WELLS

| Wellfield/Well No. | Design Flowrate (gpm) |
|---|---|
| Westmoreland Field | |
| Well No. 10 | 50 |
| Well No. 11 | 75 |
| Well No. 14 | 100 |
| Subtotal | 225 gpm (0.324 mgd) |
| Cadmus Place | |
| Well No. 2 | 70 |
| Well No. 3 | 150 |
| Well No. 4 | 90 |
| Well No. 5 | 60 |
| Well No. 6 | 65 |
| Well No. 7 | 120 |
| Subtotal | 555 gpm (0.799 mgd) |
| Memorial Park | |
| Well No. 15 | 200 |
| Well No. 16 | 175 |
| Well No. 17 | 175 |
| Well No. 19 | 275 |
| Subtotal | 825 gpm (1.188 mgd) |
| WELL No 8 | 190+ |
| Well No. 9 | 200 |
| Well No. 23 | 110 |
| Well No. 24 | 110 |
| Total All Wells | ~~2025~~ gpm (2.916 mgd)<br>2215 (3.18 MGD)+ |

## 3. ORGANIC CHEMICAL LEVELS

Existing data relating to the types and levels of VOCs which have been detected in the Borough's wells were reviewed and summarized to establish design criteria regarding influent levels for treatment facilities. In addition, as a part of this study, samples were collected from selected wells and analyzed for a series of organic compounds and for total organic carbon.

### Historical Data

In 1978, sampling and analyses of the Borough's wells indicated the presence of VOCs in several wells. Since that time, samples have been collected and analyzed to monitor VOC levels in all the wells. A summary of the Borough's sampling and analysis program at each wellfield is discussed below.

Westmoreland Wells - Historical VOC levels in the Westmoreland wells are presented in Table 3. All three wells exceed the NJDEP recommended maximum level of 100 ug/l for total VOCs. Of the Westmoreland wells, Well No. 10 has exhibited the highest levels of VOCs, while Well No. 14 has exhibited VOC levels which are considerably lower than the other two wells. Based on the results of the monitoring program and the NJDEP guidelines, the Borough has taken these wells out of service for potable use.

Of the VOCs detected in these wells, tetrachloroethylene has been found at the highest levels (as high as 1,188 ug/l in Well No. 10 on one occasion), followed by 1,1,1-trichloroethane which has been as high as 736 ug/l on one occasion in Well No. 10. The highest levels of the other VOCs generally have been less than 300 ug/l. For each of the VOCs, the highest level detected generally is two times the average level detected since monitoring for VOCs was begun.

TABLE 3

ORGANIC CONTAMINANT LEVELS
IN WESTMORELAND WELLS
(all units in micrograms/liter)

| | Well No. 10 | Well No. 11 | Well No. 14 |
|---|---|---|---|
| **Carbon Tetrachloride** | | | |
| Range | 26-130 | 10-68 | 8-35 |
| Average | 55 | 31 | 9 |
| No. of Samples(1) | 12 | 9 | 11 |
| **Trichloroethylene** | | | |
| Range | 11-185 | 46-170 | 9-59 |
| Average | 141 | 76 | 27 |
| No. of Samples | 11 | 11 | 13 |
| **Tetrachloroethylene** | | | |
| Range | 124-1,188 | 110-870 | 9-161 |
| Average | 629 | 417 | 61 |
| No. of Samples | 15 | 12 | 12 |
| **1,1,1-Trichloroethane** | | | |
| Range | 136-736 | 102-578 | 93-242 |
| Average | 439 | 267 | 141 |
| No. of Samples | 12 | 11 | 9 |
| **Chloroform** | | | |
| Range | 66-334 | 13-127 | 9-48 |
| Average | 134 | 56 | 23 |
| No. of Samples | 12 | 10 | 13 |
| **1,1-Dichloroethylene** | | | |
| Range | 16-59 | 10-16 | ND(2) |
| Average | 33 | 13 | ND |
| No. of Samples | 4 | 3 | - |
| **1,1-Dichloroethane** | | | |
| Range | 8-50 | 8-10 | 8-9 |
| Average | 24 | 9 | 9 |
| No. of Samples | 3 | 3 | 3 |

TABLE 3

ORGANIC CONTAMINANT LEVELS
IN WESTMORELAND WELLS (Cont'd)
(all units in micrograms/liter)

| | Well No. 10 | 11 | 14 |
|---|---|---|---|
| Other VOCs(3) | | | |
| Range | 2-60 | ND-13 | ND |
| Average | 20 | 10 | ND |
| No. of Samples | 5 | 2 | - |
| Total VOCs | | | |
| Average | 1475 | 879 | 270 |

Notes:

1. Number of samples in which compound was detected.
2. ND denotes "not detectable."
3. Other VOCs which have been detected in these wells include cis- or trans-1,2-dichloroethylene, 1,2-dichloroethane, trichlorofluoromethane, and methylene chloride. Concentrations represent total of other VOCs.

A review of VOC levels in these wells over the past three years indicates no definite trend of levels rising or declining. Recent analyses indicate tetrachloroethylene and 1,1,1-trichloroethane levels may be increasing slightly in Well Nos. 10 and 11, although recent levels yet are lower than the highest levels recorded for these VOCs in these wells. Levels of the other VOCs generally have been remaining steady in Well Nos. 10 and 11. Levels of all VOCs in Well No. 14 generally have been decreasing over the past year.

Cadmus Place Wells - Table 4 presents a summary of the historical VOC levels in the Cadmus Place wells. The total VOC levels in these wells have been less than the NJDEP recommended maximum level of 100 ug/l. Of the Cadmus Place wells, Well Nos. 2 and 7 generally have exhibited the highest VOC levels, while Well No. 6 has exhibited the lowest VOC levels.

Of the VOCs detected in these wells, tetrachloroethylene has been found at the highest levels (as high as 88 ug/l in Well No. 2 on one occasion), followed by trichloroethylene which has been as high as 44 ug/l in Well No. 2 on one occasion. Levels of the other VOCs generally have been less than 20 ug/l. Over the past year, VOC levels in the Cadmus Place wells have been increasing slightly, especially tetrachloroethylene levels in Well Nos. 2 and 6.

Memorial Park Wells - A summary of historical VOC levels in the Memorial Park wells is presented in Table 5. The average VOC levels in these wells have been less than the NJDEP recommended maximum level for total VOCs. Of the VOCs found in these wells, tetrachloroethylene has been detected at the highest concentration (45 ug/l on one occasion in Well No. 19), followed by 1,1,1-trichloroethane which has been as high as 33 ug/l on one occasion in Well No. 16. All

TABLE 4

ORGANIC CONTAMINANT LEVELS IN CADMUS PLACE WELLS (1)
(all units in micrograms/liter)

| | Well No. 2 | 3 | 4 | 6 | 7 |
|---|---|---|---|---|---|
| **Carbon Tetrachloride** | | | | | |
| Range | ND-1 (3) | ND-1 | ND-2 | ND-6 | ND-2 |
| Average | 1 | 1 | <1 | 1 | 1 |
| No. of Samples (2) | 7 | 5 | 6 | 10 | 11 |
| **Trichloroethylene** | | | | | |
| Range | 11-44 | 1-14 | ND-4 | ND-10 | 4-20 |
| Average | 27 | 3 | 2 | 2 | 10 |
| No. of Samples | 7 | 9 | 8 | 6 | 10 |
| **Tetrachloroethylene** | | | | | |
| Range | 12-88 | 5-42 | 4-53 | 1-11 | 10-94 |
| Average | 42 | 18 | 23 | 4 | 38 |
| No. of Samples | 8 | 10 | 12 | 14 | 11 |
| **1,1,1-Trichloroethane** | | | | | |
| Range | ND-2 | ND-1 | 1-3 | ND-8 | ND-7 |
| Average | 1 | 1 | 2 | 3 | 1 |
| No. of Samples | 6 | 3 | 4 | 11 | 9 |
| **Chloroform** | | | | | |
| Range | ND-7 | ND-6 | ND-3 | ND-30 | ND-14 |
| Average | 4 | 2 | 2 | 4 | 4 |
| No. of Samples | 4 | 6 | 4 | 11 | 7 |
| **Total VOCs** | | | | | |
| Average | 75 | 25 | 30 | 14 | 54 |

Notes:

1. VOC data for Well No. 5 were not available.
2. Number of samples in which compound was detected.
3. ND denotes "not detectable."
4. Other VOCs which have been detected in these wells on at least one occasion include cis- and trans-1,2-dichloroethylene, 1,1-dichloroethane, and 1,2-dichloroethane. Levels of these chemicals generally have been less than 10 ug/l.

TABLE 5

ORGANIC CONTAMINANT LEVELS IN MEMORIAL PARK WELLS(1)
(all units in micrograms/liter)

| | Well No. | | |
|---|---|---|---|
| | 16 | 17 | 19 |
| **Carbon Tetrachloride** | | | |
| Range | ND-5(3) | ND-7 | ND-8 |
| Average | 3 | 2 | 3 |
| No. of Samples(2) | 9 | 9 | 7 |
| **Trichloroethylene** | | | |
| Range | 3-9 | 3-10 | 2-8 |
| Average | 8 | 7 | 4 |
| No. of Samples | 7 | 7 | 7 |
| **Tetrachloroethylene** | | | |
| Range | 5-39 | 5-35 | 13-45 |
| Average | 20 | 17 | 26 |
| No. of Samples | 9 | 8 | 7 |
| **1,1,1-Trichloroethane** | | | |
| Range | ND-33 | 2-27 | ND-15 |
| Average | 15 | 8 | 3 |
| No. of Samples | 10 | 9 | 6 |
| **Chloroform** | | | |
| Range | ND-11 | ND-12 | ND-16 |
| Average | 4 | 6 | 6 |
| No. of Samples | 9 | 8 | 5 |
| **Total VOCs** | | | |
| Average | 50 | 40 | 42 |

Notes:

1. VOC data for Well No. 15 were not available.
2. Number of samples in which compound was detected.
3. ND denotes "not detectable."
4. Other VOCs which have been detected in these wells on at least one occasion include cis- and trans-1,2-dichloroethylene, 1,1-dichloroethane, and 1,2-dichloroethane. Levels of these chemicals generally have been less than 10 ug/l.

other VOCs detected in these wells have been found at levels generally below 20 ug/l. A review of VOC levels in these wells over the past year indicates that levels have been remaining the same.

Well Nos. 9 and 24 - Historical VOC concentrations for Well Nos. 9 and 24 are presented in Table 6. In Well No. 9, total VOC levels (including chloroform) have averaged slightly higher than the NJDEP recommended maximum level of 100 ug/l. Of the VOCs detected in this well, trichloroethylene has been found at the highest concentration (101 ug/l on one occasion), followed by carbon tetrachloride which has been as high as 79 ug/l on one occasion. A review of VOC levels in Well No. 9 over the past year indicates no definite trend of levels rising or declining, although total VOC levels have been less than 100 mg/l over the past year.

In Well No. 24, VOC levels have been the highest compared to all the Borough's wells. Several of the VOCs detected average over 100 ug/l. The total VOC concentration averaged 1,207 ug/l, which is above the NJDEP recommended maximum level. As a result, the Borough has taken this well out of service. Of the VOCs detected in this well, trichloroethylene has been found at the highest concentration (1,173 ug/l on one occasion), followed by chloroform which has been as high as 522 ug/l on one occasion. VOC levels in this well have varied considerably, with no definite trend of levels rising or declining.

Additional Sampling and Analyses

In addition to the historical data concerning VOCs, raw water samples were collected from the Westmoreland Field (a composite of Well Nos. 10, 11, and 14) and Well No. 24 and analyzed for 129 organic compounds [the priority pollutants,

TABLE 6

ORGANIC CONTAMINANT LEVELS
IN WELL NOS. 9 AND 24
(all units in micrograms/liter)

| | Well No. 9 | Well No. 24[3] |
|---|---|---|
| **Carbon Tetrachloride** | | |
| Range | ND-79[2] | 79-416 |
| Average | 15 | 169 |
| No. of Samples[1] | 15 | 14 |
| **Trichloroethylene** | | |
| Range | 2-101 | 139-1,173 |
| Average | 32 | 453 |
| No. of Samples | 14 | 11 |
| **Tetrachloroethylene** | | |
| Range | 2-25 | 2-36 |
| Average | 11 | 13 |
| No. of Samples | 13 | 15 |
| **1,1,1-Trichloroethane** | | |
| Range | 3-72 | 42-270 |
| Average | 26 | 177 |
| No. of Samples | 15 | 11 |
| **Chloroform** | | |
| Range | 6-53 | 78-522 |
| Average | 24 | 236 |
| No. of Samples | 15 | 14 |
| **Trans-1,2-Dichloroethylene** | | |
| Range | 17-27 | 3-269 |
| Average | 22 | 144 |
| No. of Samples | 2 | 4 |

TABLE 6

ORGANIC CONTAMINANT LEVELS
IN WELL NOS. 9 AND 24 (Cont'd)
(all units in micrograms/liter)

| | Well No. 9 | Well No. 24[3] |
|---|---|---|
| 1,1-Dichloroethylene | | |
| Range | - | ND-27 |
| Average | - | 15 |
| No. of Samples | - | 4 |
| Total VOCs | | |
| Average | 130 | 1,207 |

Notes:

1. Number of samples in which compound was detected.
2. ND denotes "not detectable."
3. Other VOCs which have been detected in this well include 1,1-dichloroethane, methylene chloride, 1,1-dichloroethylene and cis- and trans-1,2-dichloroethylene. Levels of these chemicals generally have been less than 10 ug/l.

including polychlorinated biphenyls (PCBs)] with a gas chromatography/mass spectroscopy (GC/MS) scan. A GC/MS scan identifies a wide range of both volatile and nonvolatile organic compounds included in four major groups:

- volatile fraction
- pesticide fraction
- acid fraction
- base/neutral fraction

The samples were collected by Malcolm Pirnie personnel and analyzed by Industrial Corrosion Management in Randolph, New Jersey.

The results of these analyses, presented in Appendix A, indicate that the wells contain only the volatile fraction. For the acid fraction, nothing was detected at a sensitivity level of less than 0.46 ug/l in Well No. 24 and 0.39 ug/l in the Westmoreland wells. For the base neutral fraction, nothing was detected at a sensitivity level of less than 0.37 ug/l in Well No. 24 and 0.29 ug/l in the Westmoreland wells. For the pesticides and PCBs, nothing was detected at a sensitivity level of less than 0.37 ug/l in Well No. 24 and 0.29 ug/l in the Westmoreland wells.

In addition to the GC/MS scans, raw water samples were taken at each testing site and analyzed for total organic carbon (TOC). TOC is an indicator of the presence of nonvolatile organics which can have an effect on the treatment efficiency of granular activated carbon adsorption processes for removing VOCs from ground water. Results of TOC analyses indicate relatively low levels (less than 5 ug/l) of TOC in all the wells. These results confirm the findings of the GC/MS scan and indicate that the use of GAC adsorption should not be hindered by high TOC levels.

## Design Criteria for Treatment

Based on the review of historical data and additional organics data, criteria relating to influent and effluent

VOC concentrations were established for designing treatment facilities at each of the four testing sites. Also, a hydrogeological report by Roy F. Weston, Inc. concerning the movement of VOCs in the ground water system of the Borough was reviewed.

Effluent Concentrations - As indicated in the first chapter of this report, VOCs are not currently included in federal drinking water regulations. In the absence of federal regulations, NJDEP has developed a guideline of 100 ug/l for total VOCs. Therefore, in order to meet current state guidelines, it is necessary to design treatment facilities to achieve total effluent VOC concentrations less than 100 ug/l. The NJDEP has indicated that chloroform would not be included in the total VOC calculation because of the existing regulation regarding trihalomethanes.

Currently, a federal regulation exists for trihalomethanes (THMs), which is a group of organic chemicals that includes chloroform. The maximum contaminant level for total THMs is 100 ug/l. In the Borough's wells, almost all of the THMs detected is chloroform. As a result, reducing chloroform to under 100 ug/l in the Borough's wells would achieve compliance with the federal standard.

Although federal VOC regulations currently are not available, USEPA is considering setting maximum contaminant levels (MCLs) for several VOCs. The range of potential MCLs being considered by USEPA for several VOCs detected in the Borough's wells is listed below:

| | Potential MCLs (ug/l) |
|---|---|
| Trichloroethylene | 5 to 500 |
| Tetrachloroethylene | 5 to 500 |
| Carbon Tetrachloride | 5 to 500 |
| 1,1,1-Trichloroethane | 1,000 |
| 1,2-Dichloroethane | 1 to 100 |

The range of concentrations is based on various cancer risk levels, with the low end of the range estimated to result in a lower cancer risk to the population than the high end of the range. The level for 1,1,1-trichloroethane is much higher than the level for the other VOCs because 1,1,1-trichloroethane has not been found to exhibit carcinogenic affects in humans.

In March 1982, USEPA issued an Advance Notice of Proposed Rulemaking (ANPRM) concerning VOCs in drinking water. Over the past five months, USEPA has been soliciting comments regarding the ANPRM. Based on comments received from the water supply industry and from academic groups, setting an MCL below 10 ug/l would be inconsistent with current analytical capabilities; i.e., the reliability and reproducability of analytical results below 10 ug/l is questionable. Therefore, it appears that MCLs of no less than 10 ug/l for each VOC may be ultimately proposed.

According to current USEPA schedules, a proposed regulation for VOCs may not be established until sometime in 1983, and a final regulation may not be promulgated until at least 1984. However, based on comments received on the ANRPM, it appears that most utility people feel that MCLs are needed, and it is anticipated that MCLs will be issued within the next few years.

In order to meet the current NJDEP guidelines for VOCs and to be consistent with possible future regulations, an effluent concentration of no greater than 10 ug/l for a single VOC (including chloroform) has been selected for the purpose of designing VOC treatment facilities for the Borough's wells. On this basis, the current federal regulation on THMs will be met. It is anticipated that the design of treatment facilities to reduce one VOC to 10 ug/l will result in effluent levels below 10 ug/l for the other VOCs, as discussed in more detail in a subsequent chapter of this report.

Influent VOC Concentrations - The design criteria regarding influent VOC concentrations for the Westmoreland wells are presented in Table 7. The maximum expected influent concentrations selected for design purposes for these wells generally are 20 percent greater than the maximum levels in each of these wells obtained from historical data. The design influent concentrations are higher than the maximum observed values to allow for potential increases in the VOC levels. Based on the design influent and effluent concentrations presented in Table 7, treatment facilities for this wellfield would be designed to achieve from 67 percent removal to 98.5 percent removal, depending on the type of VOC. The required total VOC removal is slightly greater than 95 percent.

The results of the Weston report indicate that the VOC plume in the groundwater is moving in a north to south direction toward the Cadmus Place wellfield and Well No. 9. The Memorial Park wellfield could also be affected in the future.

The movement of VOCs from the Westmoreland wellfield toward the Cadmus Place and Memorial Park wellfields probably will be affected by the following:

- Dilution of the highly contaminated ground water in the Westmoreland area with less contaminated ground water

- Dispersion of the VOCs to the east and west

- Retention of the majority of the VOCs in the vicinity of the Westmoreland area because of continuous pumping of the Westmoreland wells

Because of these factors, although VOC levels in the Cadmus Place and Memorial Park wells are expected to rise in the future, they are not anticipated to be as high as those currently detected in the Westmoreland wells. Also, because the Memorial Park wells are not along the direct line of the

TABLE 7

DESIGN CRITERIA FOR VOC CONCENTRATIONS AT WESTMORELAND WELLFIELD(1)

| VOC | Well No. 10 | Well No. 11 | Well No. 14 | Composite of(2) All Wells | Design Effluent Concentration | Required Percent Removal |
|---|---|---|---|---|---|---|
| Carbon Tetrachloride | 150 | 100 | 50 | 90 | 10 | 89 |
| Trichloroethylene | 200 | 200 | 100 | 160 | 10 | 94 |
| Tetrachloroethylene | 1,000 | 1,000 | 200 | 650 | 10 | 98.5 |
| 1,1,1-Trichloroethane | 750 | 600 | 300 | 500 | 10 | 98 |
| Chloroform | 300 | 150 | 50 | 140 | 10 | 93 |
| 1,1-Dichloroethylene | 75 | 25 | 10 | 30 | 10 | 67 |
| 1,1-Dichloroethane | 50 | 20 | 20 | 30 | 10 | 67 |
| Trans-1,2-Dichloroethylene(3) | - | - | - | 50 | 10 | 80 |
| Totals | 2,525 | 2,095 | 730 | 1,650 | 80(4) | 95.2 |

Notes:

1. All concentrations given in ug/l.

2. Based on design flowrates for each well of 50 gpm at Well No. 11, 75 gpm at Well No. 11, and 100 gpm at Well No. 14.

3. Data on trans-1,2-dichloroethylene not available for individual wells.

4. Actual total VOC concentration in the treated water will be much lower than 80 ug/l, as presented in Chapter 5.

expected plume path, future VOC levels in these wells are not expected to be as high as those anticipated in the Cadmus Place wells.

The design criteria regarding influent VOC concentrations in the Cadmus Place/Memorial Park wellfields are presented in Table 8. The maximum expected influent concentrations selected for design purposes in the Cadmus Place wells generally are one-half of the levels anticipated for the Westmoreland wells. The maximum expected influent concentrations selected for design purposes in the Memorial Park wells are one-quarter of the levels anticipated for the Westmoreland wells. The design concentrations allow for anticipated increases in VOC levels in these wellfields based on the above discussion of VOC movement in the ground water. Required removal efficiencies for the combined wellfields range from 82 percent removal of carbon tetravhloride to 97 percent removal of tetrachloroethylene. The required total VOC removal is 94 percent.

Design criteria regarding influent VOC concentrations at Well No. 9 are presented in Table 9. The influent VOC concentrations selected for design purposes are similar to those anticipated at the Cadmus Place wells because of the proximity of these wells. Required removal efficiencies for Well No. 9 range from 75 percent removal of 1,1-dichloroethylene to 98 percent removal of tetrachloroethylene. The required total VOC removal is 94 percent.

The design criteria concerning influent VOC concentrations at Well Nos. 23 and 24 are presented in Table 10. The influent VOC concentrations selected for design purposes are generally 20 percent higher than the highest levels observed from historical data to allow for potential increases in VOC levels. Required removal efficiencies range from 50 percent removal of 1,1-dichloroethane to 99.3 percent removal of

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TABLE 8

DESIGN CRITERIA FOR VOC CONCENTRATIONS AT CADMUS-MEMORIAL WELLFIELDS (1)

| VOC | Cadmus Wellfield | Memorial Wellfield | Composite of (2) Both Wellfields | Design Effluent Concentration | Required Percent Removal |
|---|---|---|---|---|---|
| Carbon Tetrachloride | 75 | 40 | 55 | 10 | 82 |
| Trichloroethylene | 100 | 50 | 70 | 10 | 86 |
| Tetrachloroethylene | 500 | 250 | 350 | 10 | 97 |
| 1,1,1-Trichloroethane | 350 | 175 | 250 | 10 | 96 |
| Chloroform | 150 | 75 | 110 | 10 | 91 |
| Trans-1,2-Dichloroethylene (3) | - | - | 60 | 10 | 83 |
| Totals | 1,175 | 590 | 895 | 60 (4) | 93 |

Notes:

1. All concentrations given in ug/l.

2. Based on design flowrates for each wellfield of 555 gpm at the Cadmus Wellfield and 825 gpm at the Memorial Wellfield.

3. Data on trans-1,2-dichloroethylene not available for individual wellfields.

4. Actual total VOC concentration in the treated water will be much lower than 60 ug/l, as presented in Chapter 5.

TABLE 9

DESIGN CRITERIA FOR VOC CONCENTRATIONS AT WELL NO. 9[1]

| VOC | Design Influent Concentration | Design Effluent Concentration | Required Percent Removal |
|---|---|---|---|
| Carbon Tetrachloride | 75 | 10 | 87 |
| Trichloroethylene | 100 | 10 | 90 |
| Tetrachloroethylene | 500 | 10 | 98 |
| 1,1,1-trichloroethane | 350 | 10 | 97 |
| Chloroform | 150 | 10 | 93 |
| Trans-1,2-Dichloroethylene | 40 | 10 | 75 |
| 1,1-Dichloroethylene | 40 | 10 | 75 |
| Totals | 1,255 | 70[2] | 94 |

Notes:

1. All concentrations in ug/l.

2. Actual total VOC concentration in the treated water will be much lower than 70 ug/l, as presented in Chapter 5.

TABLE 10

DESIGN CRITERIA FOR VOC CONCENTRATIONS AT WELL NOS. 23 AND 24[1]

| VOC | Design Influent Concentration | Design Effluent Concentration | Required Percent Removal |
|---|---|---|---|
| Carbon Tetrachloride | 500 | 10 | 98 |
| Trichloroethylene | 1,400 | 10 | 99.3 |
| Tetrachloroethylene | 50 | 10 | 80 |
| 1,1,1-Trichloroethane | 300 | 10 | 97 |
| Chloroform | 600 | 10 | 98 |
| 1,1-Dichloroethane | 20 | 10 | 50 |
| Trans-1,2-Dichloroethylene | 350 | 10 | 97 |
| Totals | 3,220 | 70[2] | 98 |

Notes:

1. All concentrations in ug/l.
2. Actual total VOC concentration in the treated water will be much lower than 70 ug/l, as presented in Chapter 5.

trichloroethylene. The required total VOC removal is 98 percent, which is the highest of the Borough wellfields. An alternative to treating these wells separately involves combining the flow from these wells with the flow from the Westmoreland wellfield. This strategy would help to reduce treatment requirements because of the dilution which would result from blending this water with the less affected water from the Westmoreland wells. The feasibility of this alternative is evaluated in a subsequent chapter of this report.

# 4. ORGANIC TREATMENT ALTERNATIVES

Various alternatives have been considered and evaluated for removing organic compounds from ground water supplies. This chapter presents a brief description and preliminary screening of these alternatives for removing VOCs from the Borough wells. This preliminary review was conducted as a basis for determining the most attractive alternatives for treatability testing, which is described in the following chapter.

## Available Alternatives

All available alternatives for controlling VOCs in the Borough water supply system generally fall into two basic categories:

- Management Techniques
- Treatment Techniques

Management Techniques - This category of alternative methods consists of controlling the raw water source to reduce or eliminate the VOCs. Three management techniques are:

- Eliminate compound source
- Locate new water supply
- Blend existing wells and/or supplies

Eliminating the compound source involves identification of the source of the organic compound and, subsequently, elimination of the source. However, even if the source of the compounds can be identified and eliminated, the degree of infiltration of the compounds into the aquifer may be such that many years would be required to purge the aquifer. Thus, eliminating the compound source may be an effective long-term control measure, but treatment of the Borough's water supply still would be required to permit potable use of the water.

Locating a new water supply involves abandoning the affected well(s) and locating an alternative supply which is free of organic compounds or contains compounds at lower concentrations. This may involve developing a new well into an unaffected aquifer, tapping a surface supply, or purchasing water from a neighboring community. The Borough has used the latter technique since the discovery of the organic compounds in 1978. The most affected wells (Nos. 10, 11, 14, 23 and 24) were taken out of service and additional purchases of water were made from the Passaic Valley Water Commission (PVWC) and the Hackensack Water Company (HWC) to replace the lost production capacity. In addition, the Borough plans to investigate the possibility of developing new production wells.

The major disadvantage of purchasing water from PVWC and HWC is the high cost; PVWC and HWC charge $515 and $1,500 per million gallons of water supplied, respectively. In addition, the quality of water from PVWC and HWC is generally lower than that from Borough wells. In a subsequent chapter of this report, the cost of purchasing water is compared to the cost of treating the affected well water to determine the most cost-effective VOC control technique.

The third management technique, blending, involves combining water from several wells, essentially to reduce the concentration of the compound via dilution. Depending on the levels of the compound in each well, it may be possible to reduce the concentration of the specific compound to an acceptable level by blending the water from each well prior to pumping into the distribution system. Blending of the Borough's wells, however, is not a feasible alternative because of the high VOC concentrations in the affected wells. For instance, if all of the Borough's wells were blended, the total VOC concentration would exceed 200 ug/l (based on average VOC concentrations and design flowrates). This exceeds the NJDEP guideline of 100 ug/l for total VOCs.

Nonetheless, blending of the Borough's wells can reduce treatment costs by reducing the concentration of VOCs in the combined water.

Treatment Techniques - This category of alternatives involves the use of a treatment method to reduce VOC concentrations in the well water. Treatment methods which have been considered to date include:

- Conventional treatment
- Boiling
- Reverse osmosis
- Aeration
- Adsorption

Conventional water treatment techniques, such as flocculation, clarification, and filtration, have been found to be very ineffective in removing VOCs from water. Boiling might best be considered as an emergency, or short-term, treatment technique. Although laboratory-scale tests have indicated boiling to be an effective treatment method, the use of this method on a large scale is not considered economically feasible because of the large heat requirements. Reverse osmosis has been found to be effective in removing VOCs, but this technique has not been economically and technically proven to date.

Two treatment methods which have received the most attention to date for removing VOCs from ground water supplies are aeration and adsorption. The following sections of this chapter present further descriptions of these treatment methods.

## Aeration Treatment Techniques

In water treatment, aeration is a unit process in which water and air are brought into contact with each other for the purpose of transferring volatile substances to or from water. Aeration is used as a drinking water treatment method for oxidizing iron and manganese by adding oxygen to the water, a process referred to as gas absorption. Conversely, aeration also has been used to release or strip sparingly soluble gases, such as hydrogen sulfide and carbon dioxide, from the water, a process which is referred to as air stripping. Air stripping also has been used effectively in water treatment to reduce the concentration of taste and odor producing compounds, including certain synthetic organic compounds.

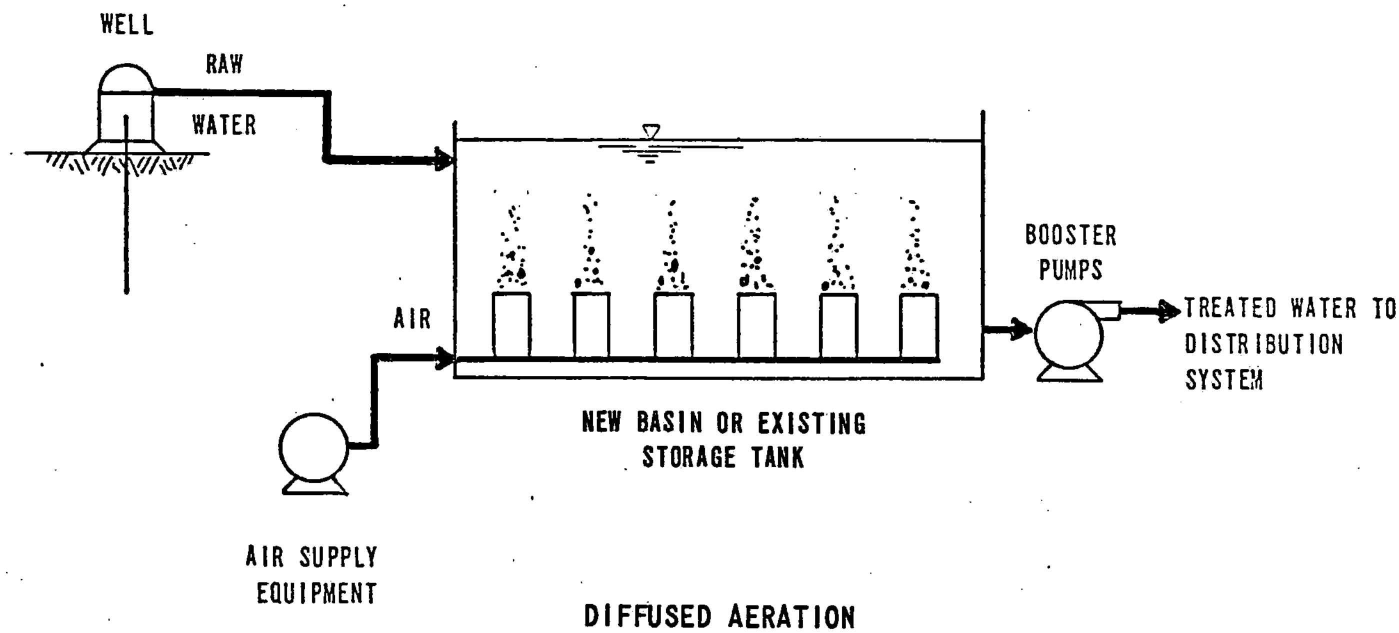
Aeration equipment presently employed in water treatment may be classified into two general categories: 1) diffused aerators, and 2) waterfall aerators, such as packed columns. Examples of each of these types of equipment are shown schematically on Figure 3.

Diffused Aeration - Air stripping is accomplished in the diffused-air type equipment by injecting bubbles of air (usually compressed air) into the water by means of submerged diffusers or porous plates. Bubbles of air are passed up through the water, thereby providing contact between the air and water to remove organics. The diffused-air basin may be a newly constructed concrete tank, or an existing tank such as a clearwell or a storage tank. The use of an existing tank would help to reduce construction costs for using diffused aeration for VOC removal.

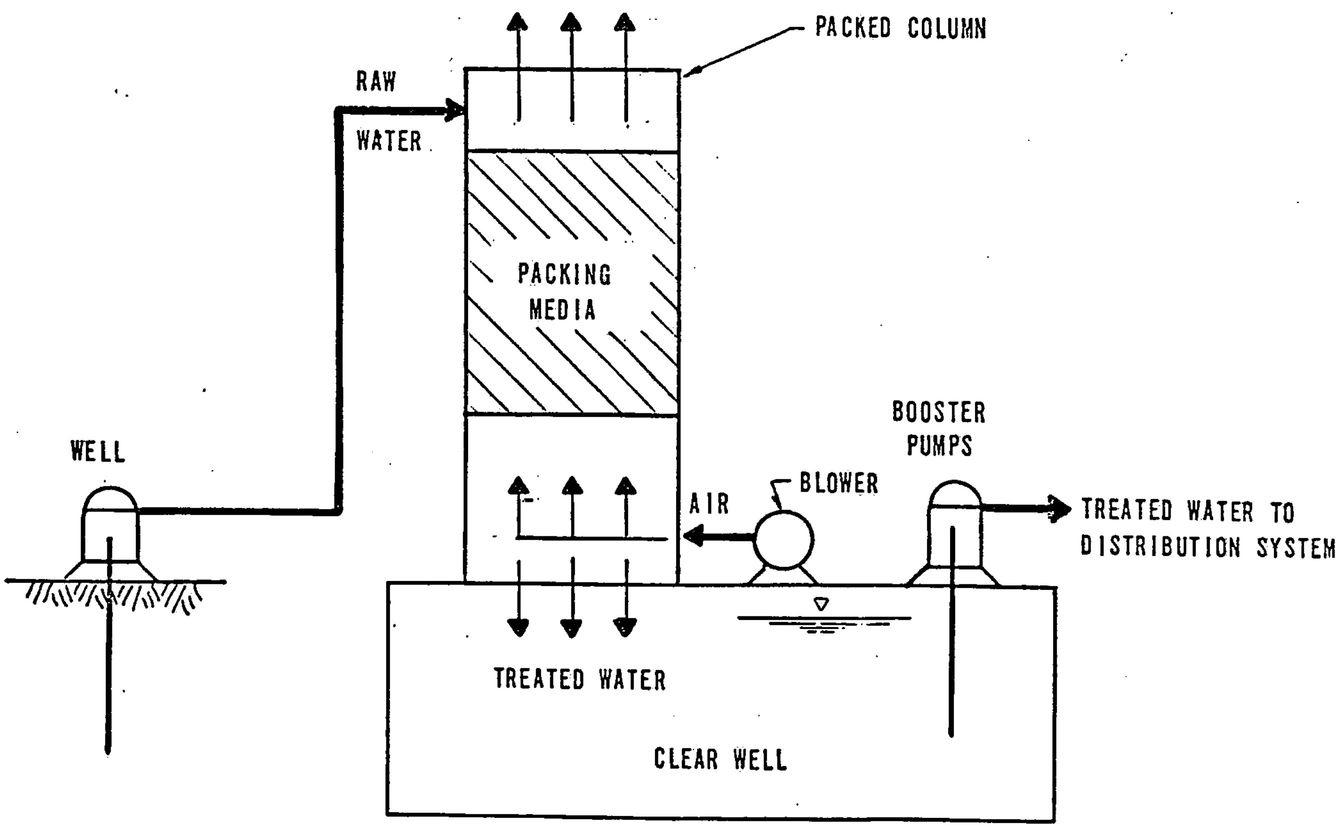
Diffused aeration has not been utilized as often as packed column aeration for VOC removal. The only major diffused aeration installation for VOC removal is located in Bristol Borough, Pennsylvania. Recently, the Borough installed diffused aeration equipment in an existing clearwell for trichloroethylene and tetrachloroethylene removal. About 80 to 90 percent removal of each of these VOCs was projected based on pilot-scale tests.

The use of diffused aeration may be a feasible technique for VOC removal at the Borough's Cadmus and Westmoreland wellfields because of the existing ground level storage

FIGURE 3




DIFFUSED AERATION




PACKED COLUMN AERATION

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS
DIAGRAM OF AERATION EQUIPMENT

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tanks at each of these sites. Raw water from the wells would be pumped to the storage tank, which would be used as the diffused air basin. Diffuser equipment would be installed in the tanks to provide sufficient air for VOC removal. Treated water would be pumped from the tanks, using the existing booster pumps, to the distribution system. Because of the need to construct basins at Well Nos. 9 and 24, diffused aeration is not considered economically feasible at these sites.

<u>Packed Column Aeration</u> - In contrast to diffused aeration, packed column aeration accomplishes the same end results by causing the water to fall through the air and break into small drops or thin films. In countercurrent packed columns, packing materials are used which provide high void volumes and high surface area. This design results in continuous and thorough contact of the water with the air and minimizes the thickness of the water layer on the packing, thus promoting efficient mass transfer of the VOCs from the water to the air.

As shown on Figure 3, water would be pumped from the wells to the top of the column(s). Air would be blown up through the column to provide a countercurrent flow of air and water. Treated water would be collected in a clearwell located directly under the column. Booster pumps would be used to pump the water back into the system. The use of packed column aeration for VOC removal is considered to be feasible at each of the Borough's wellfields and well sites.

Over the past five years, packed columns have been used successfully to remove VOCs from ground waters at several locations in the northeastern United States. In addition, pilot-scale studies conducted by Malcolm Pirnie at numerous locations have demonstrated excellent removals of VOCs using the packed column aeration process. Based on experimental and full-scale results to date, high removal efficiencies (greater than 99 percent) can be achieved through the optimum design of packed column systems. Several examples of packed column removal efficiencies which have been reported at full-scale installations are shown in Table 11.

Adsorption Treatment Techniques

The use of adsorption techniques for removing organic chemicals from drinking water has received much attention to date in the US, especially for treating large surface water supply systems. In contrast, the treatment of affected ground water supplies using adsorption techniques has only recently been the subject of pilot and full-scale plant projects. Three adsorption techniques which have been considered for removing organics from groundwaters are:

- Powdered activated carbon (PAC)
- Synthetic resins
- Granular activated carbon (GAC)

Powdered activated carbon (PAC) traditionally has been used in US water treatment plants for removing trace organic compounds associated with taste and odor problems. Fewer studies have been conducted on the use of PAC for removing organics frequently found in ground water supplies primarily because preliminary data have indicated that very large dosages of PAC would be necessary to achieve satisfactory removal efficiencies. Also, the use of PAC would require coagulation/sedimentation facilities which are not currently utilized for treating the Borough water supply.

Synthetic resins have been developed which effectively adsorb low molecular weight organics from water. The mechanism by which synthetic resins remove organic compounds is the same as that of activated carbon. One resin, Rohm & Haas Ambersorb XE 340, has been designed to remove low molecular weight, nonpolar organics, such as the halogenated organics

TABLE 11

VOC REMOVALS AT
EXISTING PACKED COLUMN INSTALLATIONS

| Location | System Size (mgd) | VOC | Percent Removal |
|---|---|---|---|
| Rockaway Township, NJ | 2.0 | Trichloroethylene | 99.99 |
| | | Diisopropyl Ether | 98 |
| | | Methyltertiary Butyl Ether | 95 |
| Warrington, PA | 0.3 | Trichloroethylene | 95 |
| Brewster, NY | 0.5 | Trichloroethylene | 92 |
| Norristown, PA | 0.01 | Trichloroethylene | 99.99 |

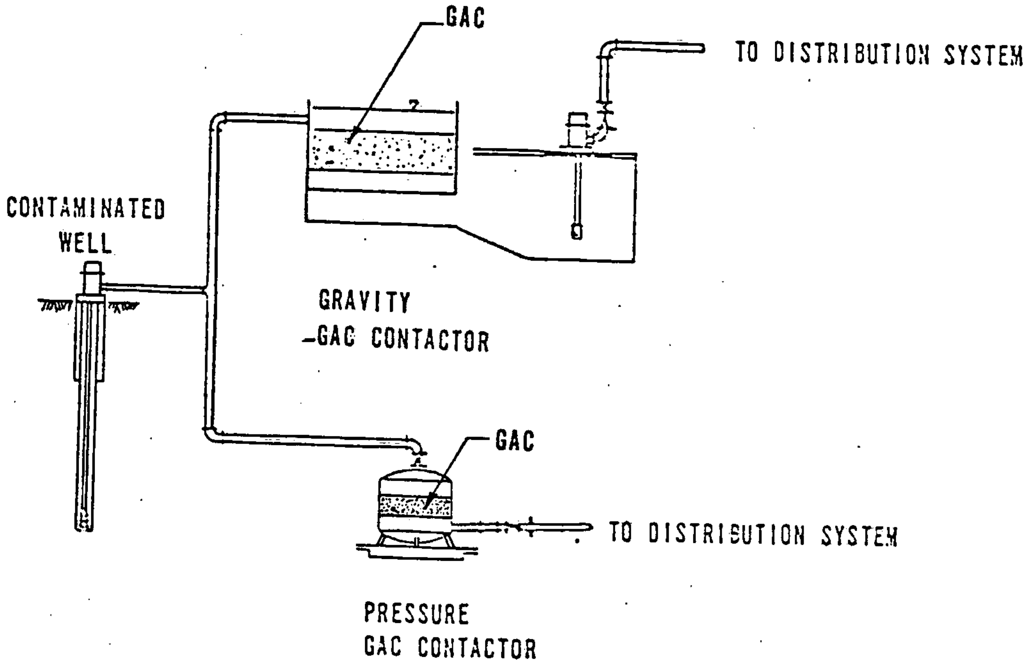
most frequently found in groundwaters. The major disadvantages of using synthetic resins are the high cost of the resins ($10 per pound compared to $0.75 per pound for carbon) and the unproven technology (especially on a full-scale) associated with regenerating the resins _in situ_ with low temperature steam.

The use of GAC for removing VOCs from ground water supplies has been evaluated to a greater extent than the use of PAC or synthetic resins. In drinking water treatment, the use of GAC in the US has been limited primarily to taste and odor control applications. However, since the widespread detection of organics in drinking water supplies, much research and many pilot-scale studies have been undertaken to evaluate the effectiveness of GAC for controlling organic compounds, more so in surface water supplies than in ground water supplies. Based on past research and pilot-scale work, many authorities feel that GAC represents the only unit process with a proven ability to remove a broad spectrum of organic chemicals from water. Although GAC is considered by many to be the best available broad spectrum removal process, it exhibits a wide range of effectiveness in adsorbing organic compounds.

The effectiveness of GAC for treating affected ground water systems depends on the types and concentrations of the organic compounds present in the ground water. Also, the presence of other synthetic or natural organics may reduce the effectiveness of the GAC to remove VOCs. As a result, pilot-scale carbon column tests are generally required to develop the necessary design criteria.

The determination of GAC contactor configuration (gravity versus pressure) depends upon the existing characteristics of the ground water supply system. Each of these types of GAC treatment systems are shown schematically on Figure 4. The use of gravity GAC contactors would require repumping

FIGURE 4

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS
GAC TREATMENT OPTIONS

following treatment, as illustrated on Figure 4. In contrast, it may be possible to eliminate the need for repumping by using pressure contactors where the raw water is pumped from the well, through the contactor, and then into the distribution system, as illustrated on Figure 4. In evaluating the use of pressure contactors, consideration must be given to existing system hydraulics to ensure proper operation of the contactor and to maintain adequate pressures throughout the distribution system.

An important economic consideration regarding the use of a GAC treatment system is regeneration of the carbon. Manufacturers of GAC indicate that on-site regeneration is not economical at carbon usage rates of less than 2,000 pounds per day. On this basis, most affected ground water systems find that off-site regeneration is more economical than regenerating carbon on-site.

In the past several years, GAC treatment systems have been used for VOC removal at several locations, as shown in Table 12. The expected life of the carbon at each of these installations varies because of the different types and concentrations of VOCs at each site. At several sites, it has been necessary to replace the carbon two or more times per year.

The use of GAC adsorption for VOC removal is considered to be feasible at each of the Borough's wellfields and well sites. To eliminate the need for repumping, pressure contactors would be more applicable than gravity contactors.

Summary of Feasible Alternatives

Based on the above discussion, the most feasible techniques for removing VOCs from the Borough wells are packed column aeration, diffused aeration and GAC adsorption. Because only VOCs have been detected in the Borough's wells, aeration alone can be used for treatment, and GAC is not

TABLE 12

FULL-SCALE GAC
ADSORPTION INSTALLATIONS

| Location | VOCs | System Size (mgd) | Expected[1] GAC Life |
|---|---|---|---|
| Rockaway Borough, NJ | Trichloroethylene<br>Tetrachloroethylene | 1.5 | 7 months |
| Boonton, NJ | 1,1,1-Trichloroethane<br>Trichloroethylene | 1.0 | 3-12 months |
| Smyrna, Del. | Trichloroethylene | 2.6 | 9 months |
| Lansdale, PA | Trichloroethylene | 0.15 | 4 months |
| Washington Township, NJ | Tetrachloroethylene<br>Carbon Tetrachloride<br>Chloroform | 0.8 | 6 months |

Note:

1. The expected life of the GAC is defined as the time after which the GAC must be replaced because the VOC removal is insufficient.

needed to "polish" the aerated water. These treatment techniques have been demonstrated to be capable of removing VOCs from ground water supplies. However, because of limited work to date on the removal of VOCs using these treatment systems, pilot-scale testing is necessary to verify removal efficiencies and to develop design criteria for full-scale facilities.

As a result, these treatment techniques were selected for detailed pilot testing at the Borough's wellfields and well sites as follows:

- Diffused Aeration: Westmoreland and Cadmus Wellfields.
- Packed Column Aeration: Westmoreland and Cadmus Wellfields, Well Nos. 9 and 24.
- GAC Adsorption: Westmoreland and Cadmus Wellfields; Well Nos. 9 and 24.

The results of the pilot testing are discussed in the following chapters.

# 5. PACKED COLUMN AERATION TREATABILITY TESTING PROGRAM

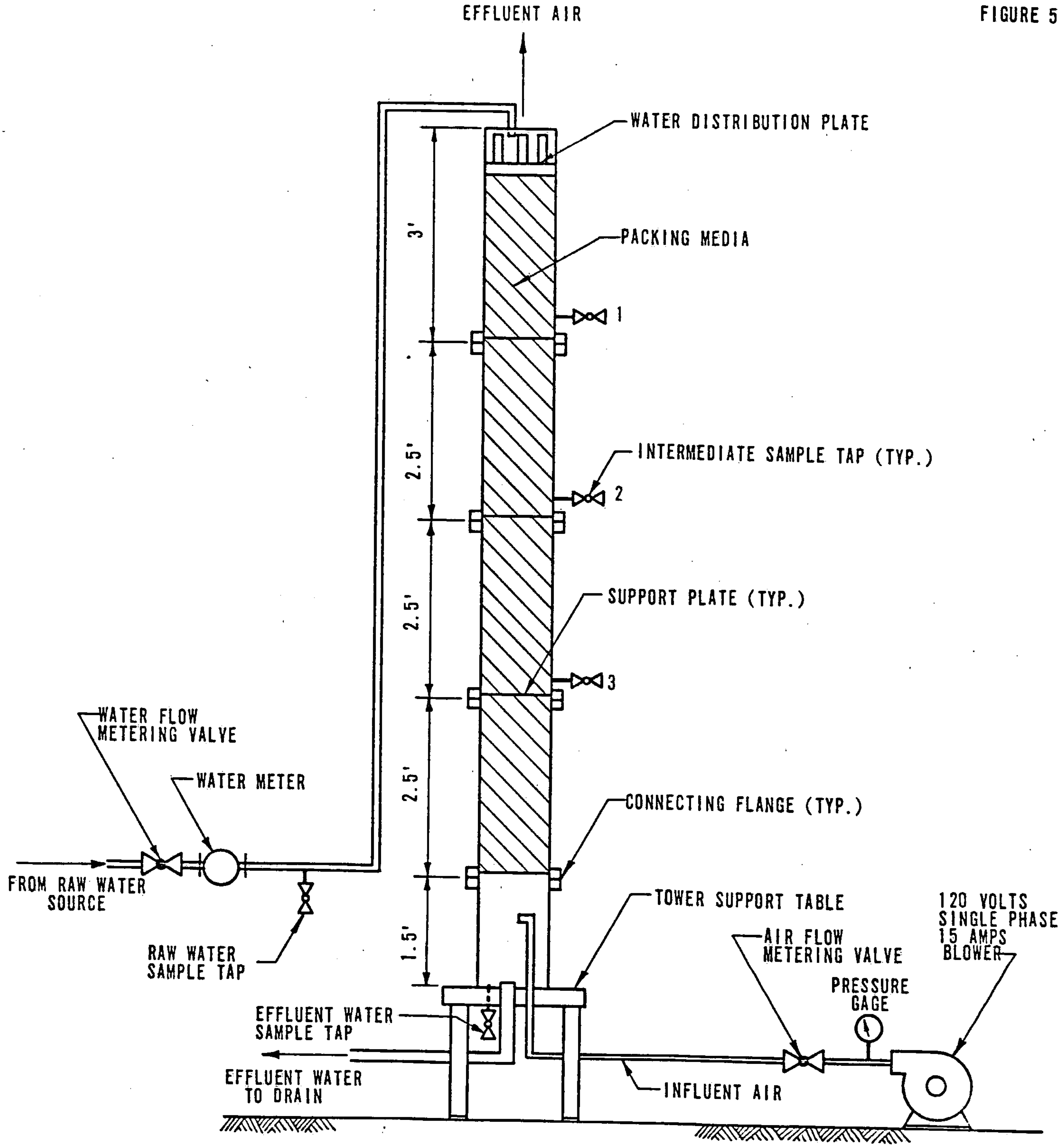
As part of this study, a pilot-scale testing program was conducted at four locations to evaluate removal efficiencies using the packed column aeration process and to develop design criteria for full-scale treatment facilities. Pilot-scale tests were conducted at the Westmoreland Wellfield, Cadmus Place Wellfield, Well No. 9 and Well No. 24. A description of the pilot tests and an evaluation of the test results are presented in this chapter.

## Description of Testing Equipment

The treatability tests were conducted using a pilot aeration column, which has been designed and fabricated by Malcolm Pirnie. The pilot column consists of influent piping and valves, the column and packing media, a blower and a support structure. A diagram of the pilot column is shown on Figure 5. Raw water is pumped from the well through the metering valve and water meter to the top of the column, trickles down through the packing media, and is discharged by gravity flow. Air is forced by two Rotron regenerative blowers through a pressure gage and a metering valve to the bottom of the column, up through the column, and into the atmosphere. Sample taps are provided on the influent line, at three locations along the side of the column, and at the bottom of the column for collecting raw and treated water samples.

The column is 12 inches in diameter and is constructed of PVC pipe in five sections for variation of packing depth and ease of handling. The maximum packing depth is 9.5 feet, and the overall column height is 12 feet. An orifice-type liquid distributor is used to distribute water at the top of the column. Support plates have been placed between each

FIGURE 5




BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

DIAGRAM OF PILOT AERATION COLUMN

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column section to provide intermediate support of the media and to redistribute water and air flow to reduce channelization in the column. The column is designed for a maximum hydraulic loading of 50 gallons per minute. The blowers have a range of 0 to 160 cubic feet per minute.

Several types of packing media were evaluated during the pilot tests. For testing most of the Borough wells, the column was packed with 2-inch Jaeger Tri-Packs. One and 2-inch Ceilcote Tellerettes also were evaluated at the Westmoreland Wellfield.

Description of Treatability Tests

The rate at which a volatile organic compound is removed from water by aeration (or the mass transfer characteristics of the compound) depends on several factors:

- hydraulic loading rate (or water flow rate)
- air flow rate
- air:water (A:W) ratio
- available surface area for mass transfer
- temperature of the water and air
- physical chemistry of the compound

The latter two factors were constant and were not altered during the tests of the Borough wells. The design factors which were varied during the pilot tests were the water flowrate, the air flowrate, the A:W ratio, and the available area for mass transfer.

Various types of packing material are available for air stripping processes. For testing the Borough wells, 1-inch and 2-inch Tellerettes and 2-inch Tri-Packs were selected for evaluation. The selection of the Tellerettes was based on the results of pilot testing conducted by Malcolm Pirnie at 10 other well sites which indicated that the Tellerettes had better mass transfer characteristics when compared to other types of packing. The selection of the Tri-packs was based on manufacturer's information which indicated that this type of packing has excellent mass transfer characteristics, low pressure loss and low cost. The 1-inch and 2-inch Tellerettes and 2-inch Tri-packs were compared at the Westmoreland Wellfield. Based on the results of this comparison the optimum packing was used at the other three testing sites.

The A:W ratio is dependent upon the water and air flowrates. During the pilot tests, the water and air flowrates were varied to obtain several A:W ratios. By monitoring VOC removal efficiencies under these various conditions, data for developing the mass transfer relationship for each VOC and each well were obtained.

At each of the wells tested, the pilot column was set-up and operated at several A:W ratios. For each run, the water and air flowrates were adjusted to yield the desired A:W ratio, and then the column was operated for about 30 minutes to permit the column to reach a steady state. For all the wells, the well pump was operated at the normal flowrate and a sidestream of 20 to 30 gpm was piped to the pilot unit. Data concerning the operating conditions under which the tests were conducted are presented in Appendix B at the end of this report.

For each run, influent and effluent samples were collected, along with air and liquid flowrates, and air and water temperatures. Samples were collected in properly prepared sample vials for VOC analysis in accordance with EPA protocol. Analyses for VOCs were conducted at Malcolm Pirnie's laboratory in White Plains, New York with a gas chromatograph utilizing the purge and trap method. In addition, influent and effluent samples were collected during selected runs for analyses of several parameters (pH, alkalinity, calcium hardness, total dissolved solids and dissolved oxygen) to determine the effects of aeration on the corrosivity of the water.

Results of Testing Program

The results of the pilot-scale aeration tests are presented in Appendix B and summarized in Tables 12, 13, 14 and 15 for Westmoreland, Cadmus-Memorial, Well No. 9 and Well No. 24, respectively. In general, the test results indicate the following:

1. High removal efficiencies can be obtained for all of the VOCs detected in the Borough's water through the use of the packed column aeration process; even with no induced draft, some removal of VOCs probably will be achieved.

2. The mass transfer relationship for each VOC for each testing site was determined from the data and found to increase as the water flowrate was increased; also, the mass transfer was found to vary from one well site to another.

3. Increasing the A:W ratio results in an increase in the removal efficiency of the column. The mass transfer coefficients with the Tri-packs generally were equal to those with the Tellerettes. Based on these results and the relatively low cost of the Tri-packs, this type of packing was determined to be optimum.

4. Aeration of the water does not adversely affect the corrosivity of the water based on a review of the calcium carbonate stability and dissolved oxygen concentration of the water.

5. Transferring the VOCs from the water to the air should not create an air pollution problem.

The first three conclusions are expanded upon for each of the four testing sites in the following sections. The latter two conclusions are discussed for all of the tests at the end of the chapter. Also, design criteria based on the results of the pilot tests are presented at the end of this chapter.

Westmoreland Wellfield

The initial pilot column testing was conducted at the Westmoreland Wellfield. Twenty-two tests were performed, in which three types of packing material were evaluated. The packing material were 1-inch and 2-inch Tellerettes and 2-inch Tri-packs. The packed column influent was obtained from the main which conveys water from Well Nos. 10, 11 and 14 to the ground-level storage tank at the Westmoreland Wellfield.

Removal Efficiency - The results presented in Table 13 consist of the highest and lowest air-to-water ratios evaluated and represent the range of removal efficiencies achieved during the pilot testing. In general, the removal efficiencies for all of the VOCs were greater than 80 percent. A removal efficiency for TCE of as high as 99 percent was achieved with less than 10 feet of packing media and an A:W ratio of 100:1. The test results also indicate that PCE and 1,1,1-trichloroethane are more easily removed than the other compounds. These relative removals generally are consistent with theoretical principles of gas mass transfer, which indicate that the transfer of a compound from a liquid to a gas depends on the Henry's Law Constant of the compound. A compound with a high Henry's Law Constant generally is more easily removed from water using aeration than one with a lower constant. Of the VOCs found at the highest concentration in the Borough wells, PCE and 1,1,1-trichloroethane have Henry's Law Constants of 1.2, while TCE and chloroform have constants of 0.49 and 0.12, respectively. Therefore, one would expect that PCE and 1,1,1-trichloroethane would be more easily removed than TCE and chloroform. Inconsistencies in the data are due mainly to very low VOC concentrations (<2 ug/l) in the aerated water. The gas chromatograph analyses are less accurate at these levels and the results tend to distort the computed removal efficiencies.

TABLE 13

PILOT PACKED COLUMN AERATION
TEST RESULTS -- WESTMORELAND WELLFIELD

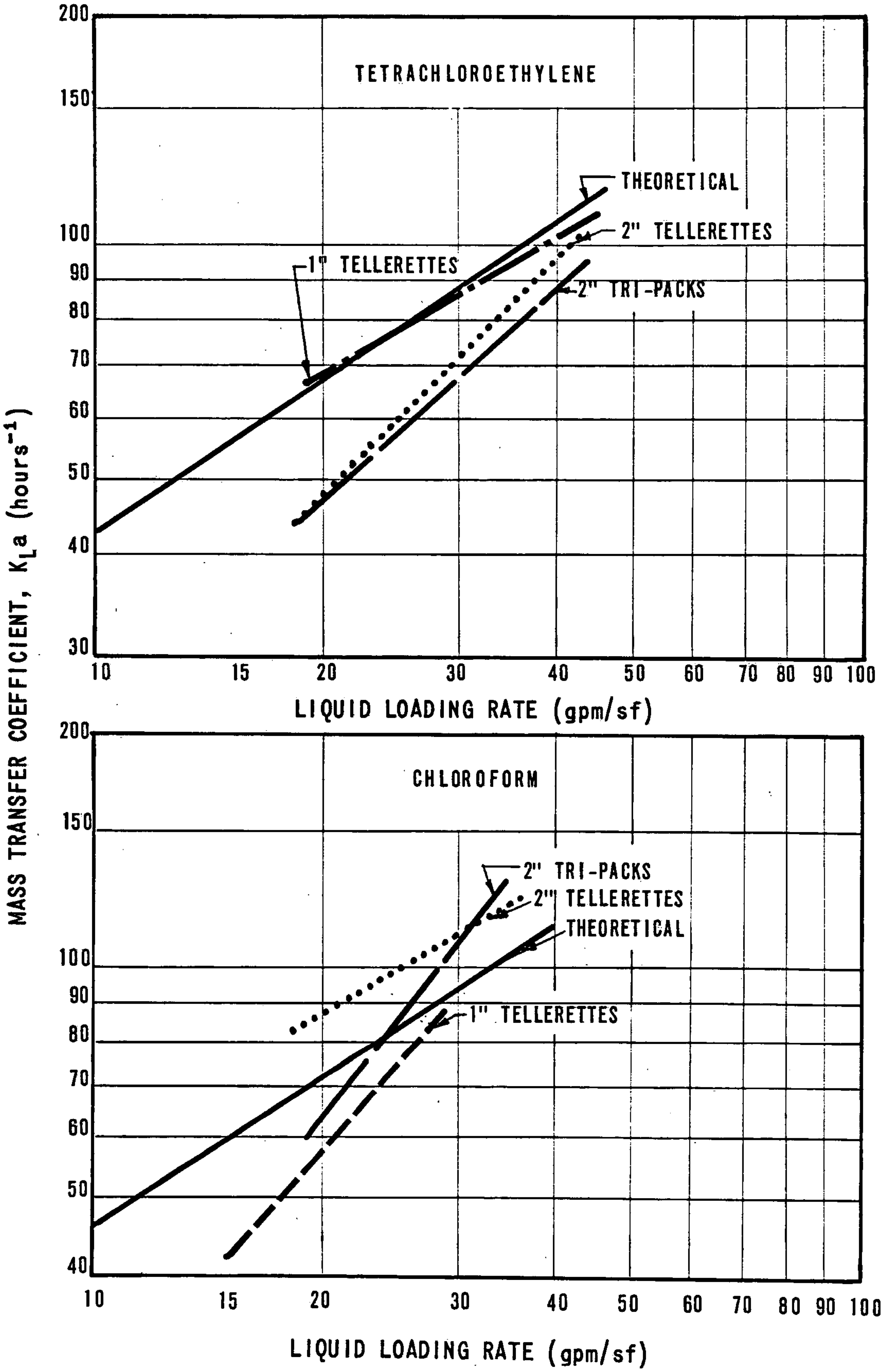
| Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Packing Material | Compound | Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|---|
| 12 | 160 | 100:1 | 2-inch Tellerettes | Trichloroethylene | 13 | 0.1 | 99 |
| | | | | Tetrachloroethylene | 31 | 0.3 | 99 |
| | | | | 1,1,1-Trichloroethane | 82 | 2 | 98 |
| | | | | Chloroform | - | - | - |
| 28 | 37 | 10:1 | 2-inch Tellerettes | Trichloroethylene | 15 | 2.0 | 87 |
| | | | | Tetrachloroethylene | 32 | 3 | 91 |
| | | | | 1,1,1-Trichloroethane | 84 | 12 | 86 |
| | | | | Chloroform | 12 | 7 | 42 |
| 12 | 160 | 100:1 | 1-inch Tellerettes | Trichloroethylene | 16 | <1 | >94 |
| | | | | Tetrachloroethylene | 61 | 1 | 98 |
| | | | | 1,1,1-Trichloroethane | 81 | 2 | 98 |
| | | | | Chloroform | 18 | <1 | >94 |
| 28 | 37 | 10:1 | 1-inch Tellerettes | Trichloroethylene | 6 | 3 | 50 |
| | | | | Tetrachloroethylene | 15 | 6 | 60 |
| | | | | 1,1,1-Trichloroethane | 59 | 14 | 76 |
| | | | | Chloroform | 106 | 3 | 94 |
| 15 | 160 | 80:1 | 2-inch Tri-packs | Trichloroethylene | 67 | 2.7 | 96 |
| | | | | Tetrachloroethylene | 314 | 18 | 92 |
| | | | | 1,1,1-trichloroethane | 131 | 5.8 | 96 |
| | | | | Chloroform | 25 | <1 | >96 |
| 28 | 56 | 15:1 | 2-inch Tri-packs | Trichloroethylene | 67 | 16 | 76 |
| | | | | Tetrachloroethylene | 455 | 58 | 87 |
| | | | | 1,1,1-trichloroethane | 178 | 20 | 89 |
| | | | | Chloroform | 52 | 7 | 87 |

Based on the results of packed column tests conducted at other well sites, even when no induced draft is applied to the column, some removal (20-50 percent) of each VOC is achieved. Therefore, under full-scale operation of the column, about 35 percent removal of the VOCs may be expected even if the column is operated without the blowers on-line during maintenance or repair.

<u>Mass Transfer Relationships</u> - In order to use the results of the pilot tests for the design of full-scale aeration columns, VOC mass transfer relationships were determined for the combined water from Well Nos. 10, 11 and 14. For each run, a mass transfer coefficient was calculated from the water flowrate, the A:W ratio, and the water temperature. The data then were evaluated using a linear regression analysis. A plot of the mass transfer coefficient for each type of packing material as a function of the water flowrate was developed and plotted as shown on Figures 6 and 7. The theoretical relationship between the mass transfer coefficient for the VOCs and the water flowrate also is plotted.

As shown on Figures 6 and 7, the mass transfer coefficients for all the VOCs were relatively similar regardless of the type of packing used. In a full-scale operation, the 1-inch Tellerettes would cause a higher pressure drop in the air flow than the 2-inch Tellerettes or the 2-inch Tri-packs, requiring larger blowers to compensate for the pressure drop. As a result, the 2-inch packing would be best used in a full-scale packed column.

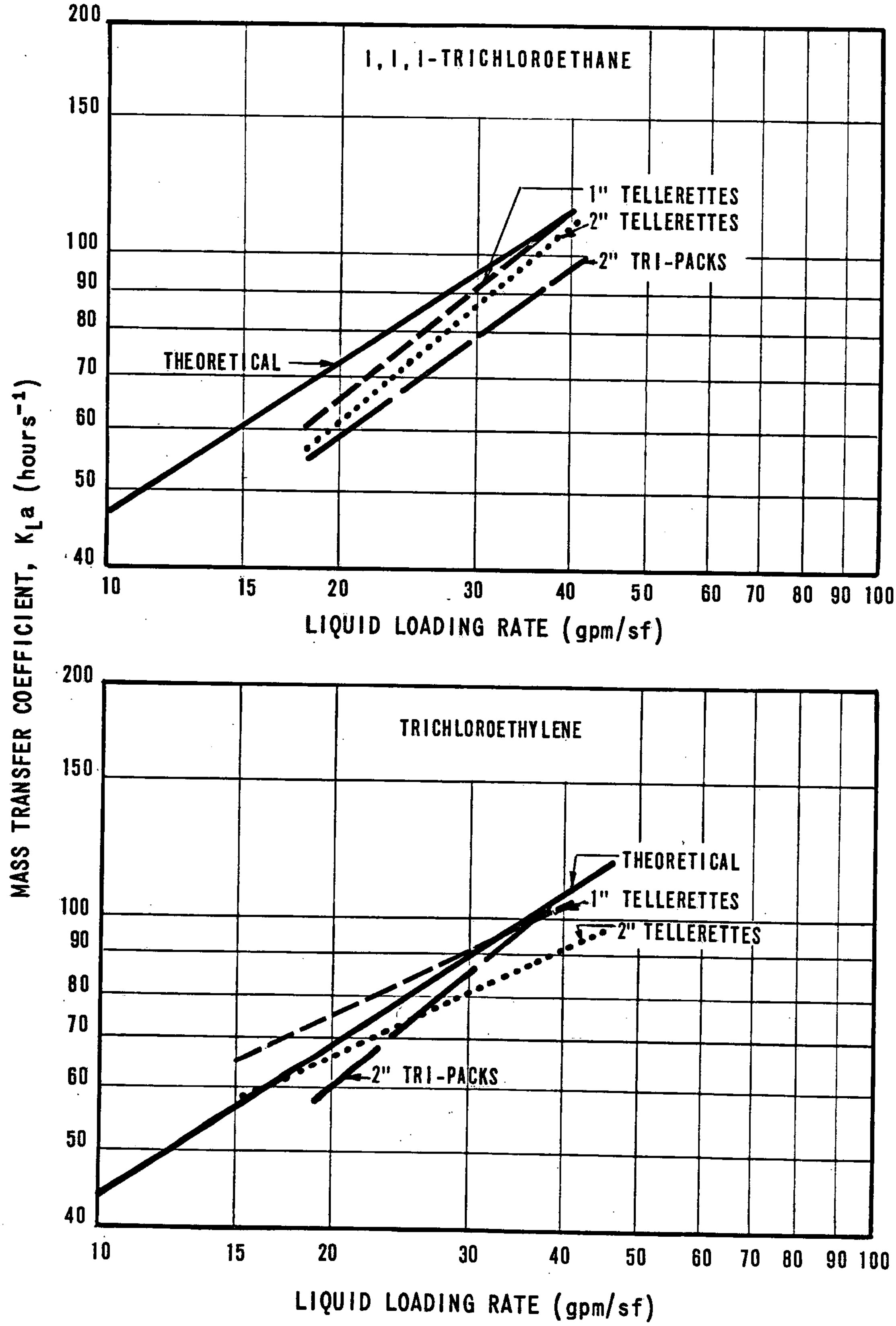
The comparison of the 2-inch Tellerettes and Tri-packs indicate that the mass transfer coefficients with 2-inch Tellerettes were equal to or slightly greater than those with the 2-inch Tri-packs. On this basis the 2-inch Tellerettes would appear to be the optimum packing. However, the 2-inch Tellerettes are more costly than the 2-inch Tri-packs, and the slightly better mass transfer characteristics of the




MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

COMPARISON OF PACKING MATERIAL
WESTMORELAND WELLS




MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

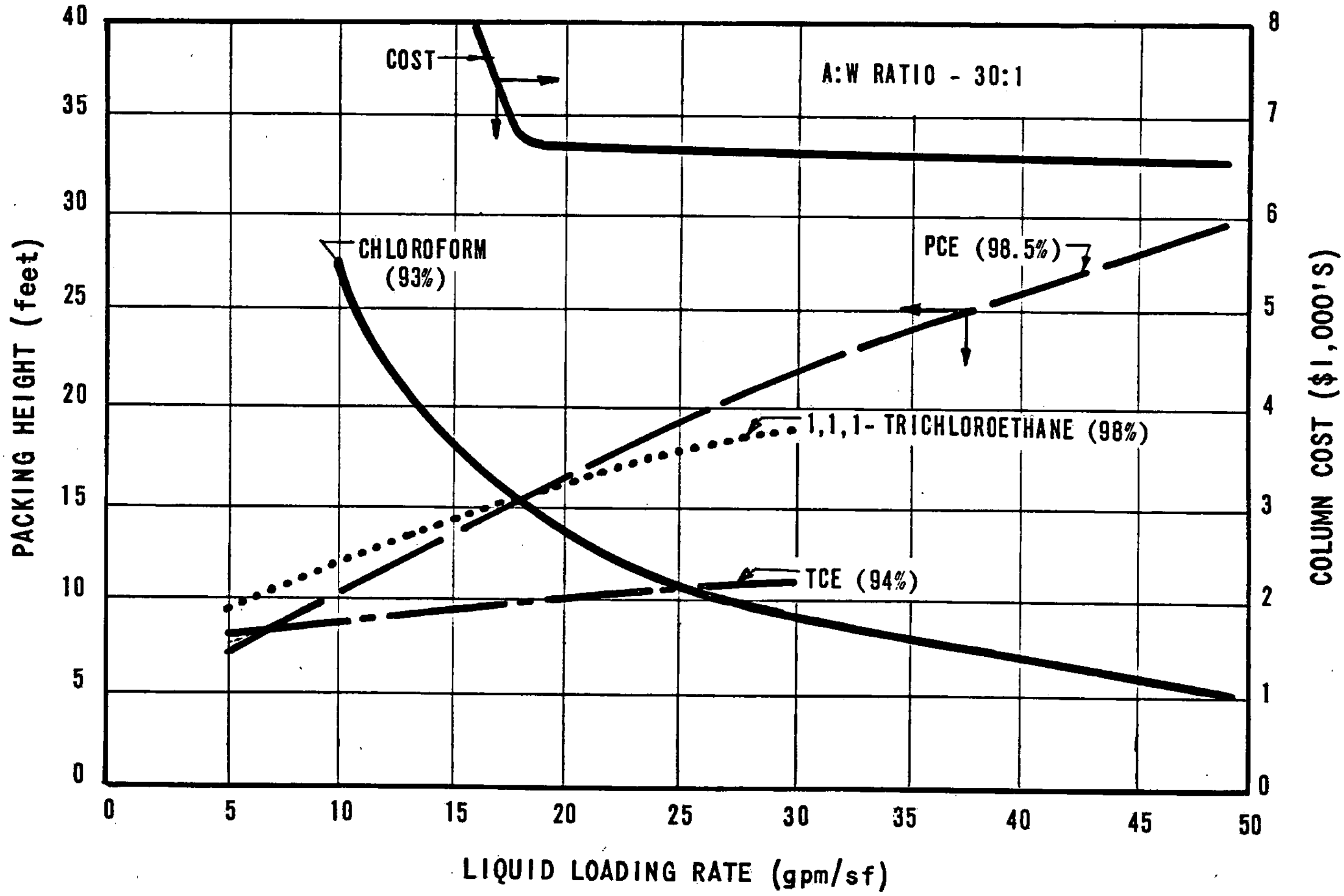
COMPARISON OF PACKING MATERIAL
WESTMORELAND WELLS

Tellerettes do not justify their higher cost. As a result, the 2-inch Tri-packs were determined to be the optimum packing material based on performance and cost and were selected for use in testing at the other wellfields.

As indicated on Figures 6 and 7, the actual mass transfer relationships developed from the pilot test data generally are less than the theoretical relationship. The implication of these results is the need for slightly higher towers than those determined from theoretical calculations. The test results for chloroform, as shown on Figure 6, shown somewhat better mass transfer relationships than those predicted from theoretical calculations, indicating rather efficient operation of the pilot column.

Based on the relationship between mass transfer coefficients and liquid loading rate developed above, the optimum liquid loading rate was determined by plotting the required packing height as a function of liquid loading rate for each VOC as shown on Figure 8. The removal efficiency for each compound is based on the design criteria established in Chapter 3 and the use of 2-inch Tri-packs. The air-to-water ratio was approximated at 30:1. In addition, the cost for a packed column shell and packing for the critical compound at each liquid loading rate is plotted. The critical compound is the VOC which requires the highest degree of treatment, and thus determines the design of the packed column.

As indicated on Figure 8, the critical compound at the Westmoreland Wellfield is chloroform at loading rates less than 18 gpm/sf. At loading rates greater than 18 gpm/sf, PCE is the critical compound. Packed column costs decrease up to 18 gpm/sf and are relatively constant above 18 gpm/sf. Column costs are constant at loading rates greater than 18 gpm/sf because the cost savings due to the decrease in diameter as a result of the increased loading rate is offset by extra costs due to the increase in packing height. Thus,




NOTE: (98.5%) DENOTES 98.5 PERCENT REMOVAL OF COMPOUND.

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

LIQUID LOADING RATE vs
PACKING HEIGHT-
WESTMORELAND WELLS

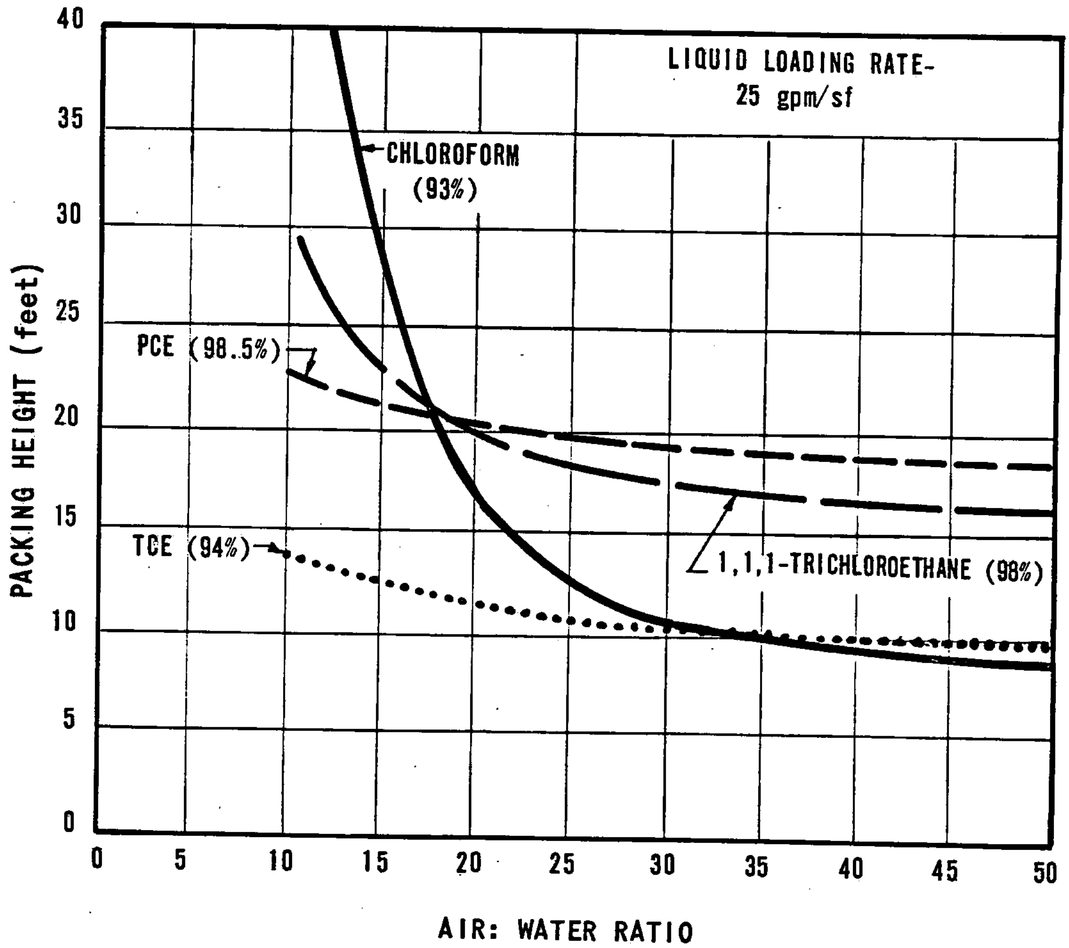
based on Figure 8 and past experience, the design liquid loading rate for the Westmoreland Wellfield was determined to be 25 gpm/sf. The use of this liquid loading rate results in the lowest packing height and the lowest column cost.

A:W Ratio - In general, the test results indicate that increasing the A:W ratio causes an increase in the VOC removal efficiency. The relationship between the A:W ratio and the required packing height was determined for the Westmoreland wells for the desired VOC removals. These relationships are shown graphically on Figure 9. As indicated on the graph, initially increasing in the A:W ratio results in a significant reduction in the required packing height. However, beyond an A:W ratio of 30 to 40:1, the reduction in the packing height becomes less significant. Therefore, the optimum A:W ratio was determined to be 40:1. The corresponding packing height is approximately 20 feet. As indicated previously, the design criteria for the Westmoreland Wellfield are summarized at the end of this chapter.

Cadmus Place-Memorial Park Wellfields

Seven packed column tests were conducted at the Cadmus Place Pumping Station with water from the combined Cadmus Place-Memorial Park wells. The packed column influent was obtained from the discharge of one of the Cadmus Place booster pumps and was considered to be representative of the combined water from the two wellfields. Well Nos. 5 and 15 were out of service during the testing period.

Removal Efficiency - A summary of the test results indicating the range of removal efficiencies for the Cadmus-Memorial wells is presented in Table 14. Four compounds were detected in the Cadmus-Memorial water at relatively low concentrations: trichloroethylene, tetrachloroethylene, chloroform and trans-1,2-dichloroethylene. The removal




NOTE: (98.5%) DENOTES 98.5 PERCENT REMOVAL OF COMPOUND.

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS
A:W RATIO vs PACKING HEIGHT-
WESTMORELAND WELLS

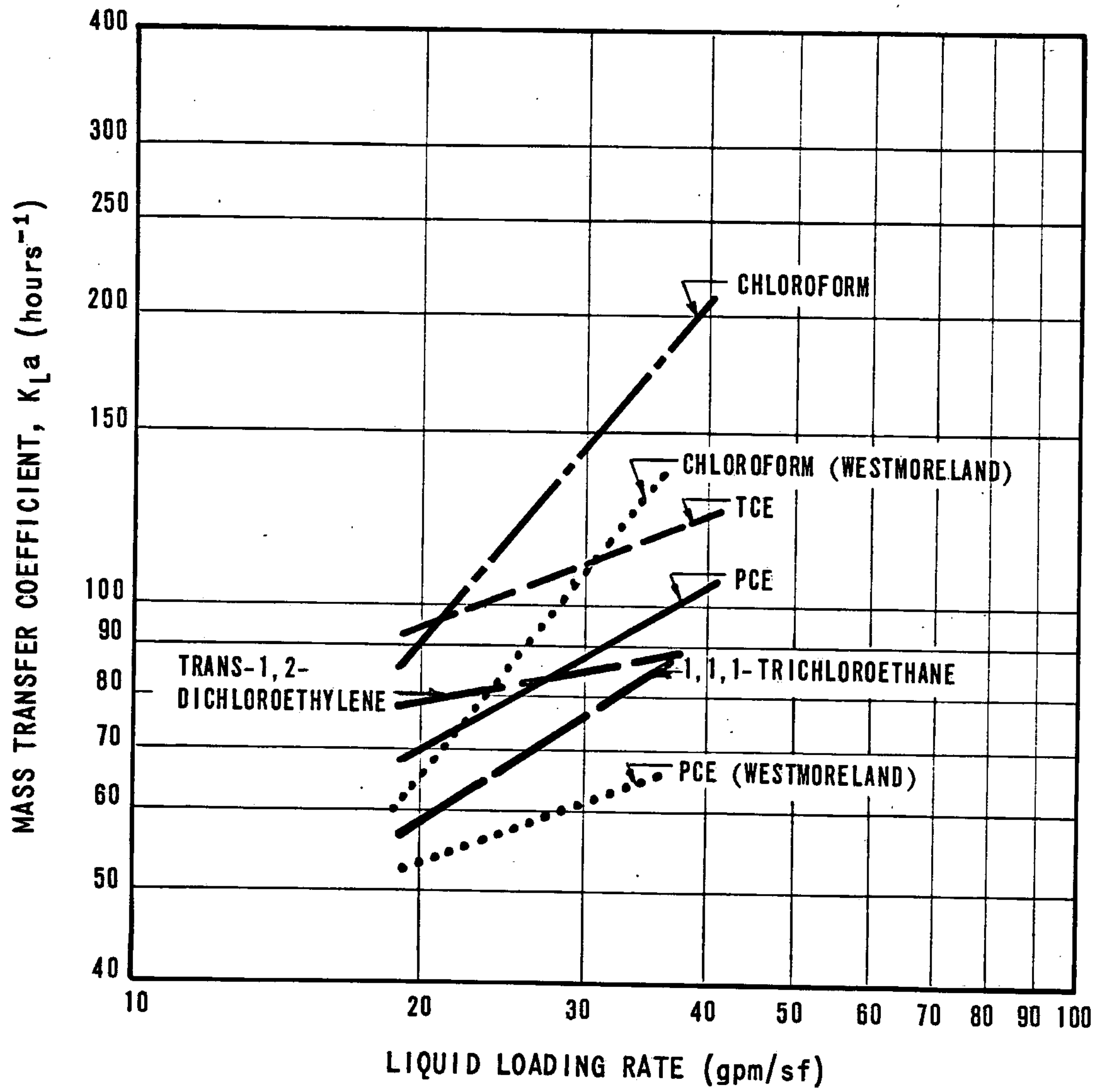
TABLE 14

PILOT PACKED COLUMN AERATION TEST RESULTS
CADMUS PLACE -- MEMORIAL PARK WELLFIELDS

| Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Packing Material | Compound | Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|---|
| 15 | 160 | 80:1 | 2-inch Tri-packs | Trichloroethylene | 2.1 | 0.1 | 95 |
| | | | | Tetrachloroethylene | 11 | 1.1 | 90 |
| | | | | Trans-1,2-dichloroethylene | 8.5 | 0.7 | 92 |
| | | | | Chloroform | 12.5 | <1 | >92 |
| 27 | 72 | 20:1 | 2-inch Tri-packs | Trichloroethylene | 2.1 | 0.5 | 76 |
| | | | | Tetrachloroethylene | 9.7 | 3.3 | 68 |
| | | | | Trans-1,2-dichloroethylene | 11 | 2.7 | 76 |
| | | | | Chloroform | 13 | <1 | >92 |

efficiencies for these compounds were greater than 90 percent at the highest A:W ratio and greater than 60 percent at the lowest A:W ratio. In general, trichloroethylene and chloroform were more easily removed than tetrachloroethylene and trans-1,2-dichloroethylene. These results conflict with the expected results from the Henry's Law constants for these VOCs, which indicate the opposite of the test results. This inconsistency may be explained by the reduced accuracy of the analytical equipment when measuring very low levels of VOCs, such as those in the Cadmus Place and Memorial Park wells.

Mass Transfer Relationships - A plot of the mass transfer coefficient as a function of water flowrate for the Cadmus-Memorial tests is shown on Figure 10. Chloroform and 1,1,1-trichloroethane had the highest and lowest mass transfer coefficients, respectively. The relative values of the mass transfer coefficients for the various compounds generally agree with the results from the Westmoreland Wellfield. There are significant differences, however, in the mass transfer coefficients for the same compound at the different testing sites. For example, the mass transfer coefficients for chloroform and PCE for the Westmoreland wells are plotted on Figure 10. For both compounds, the mass transfer coefficient at all water flowrates are about 25 percent greater for the Cadmus-Memorial wells than for the Westmoreland wells. The reason for the variation in mass transfer relationships between wells is difficult to identify. One reason may be the different characteristics of the water, possibly the different levels of VOC contamination. Variations in mass transfer relationships between wells have been found at other test sites, with no readily identifiable explanation to date. The implication of these results is the need for slightly higher columns at those sites with lower mass transfer coefficients.

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

MASS TRANSFER RELATIONSHIPS-
CADMUS PLACE - MEMORIAL PARK

The relationships between liquid loading rate, packing height, and packed column cost are shown on Figure 11. The critical compound is 1,1,1-trichloroethane. Based on the packed column cost curve, the optimum liquid loading appears to be 25 gpm/sf. Packed column costs increase at liquid loading rates less than 25 gpm/sf, but do not decrease significantly at loading rates greater than 25 gpm/sf.

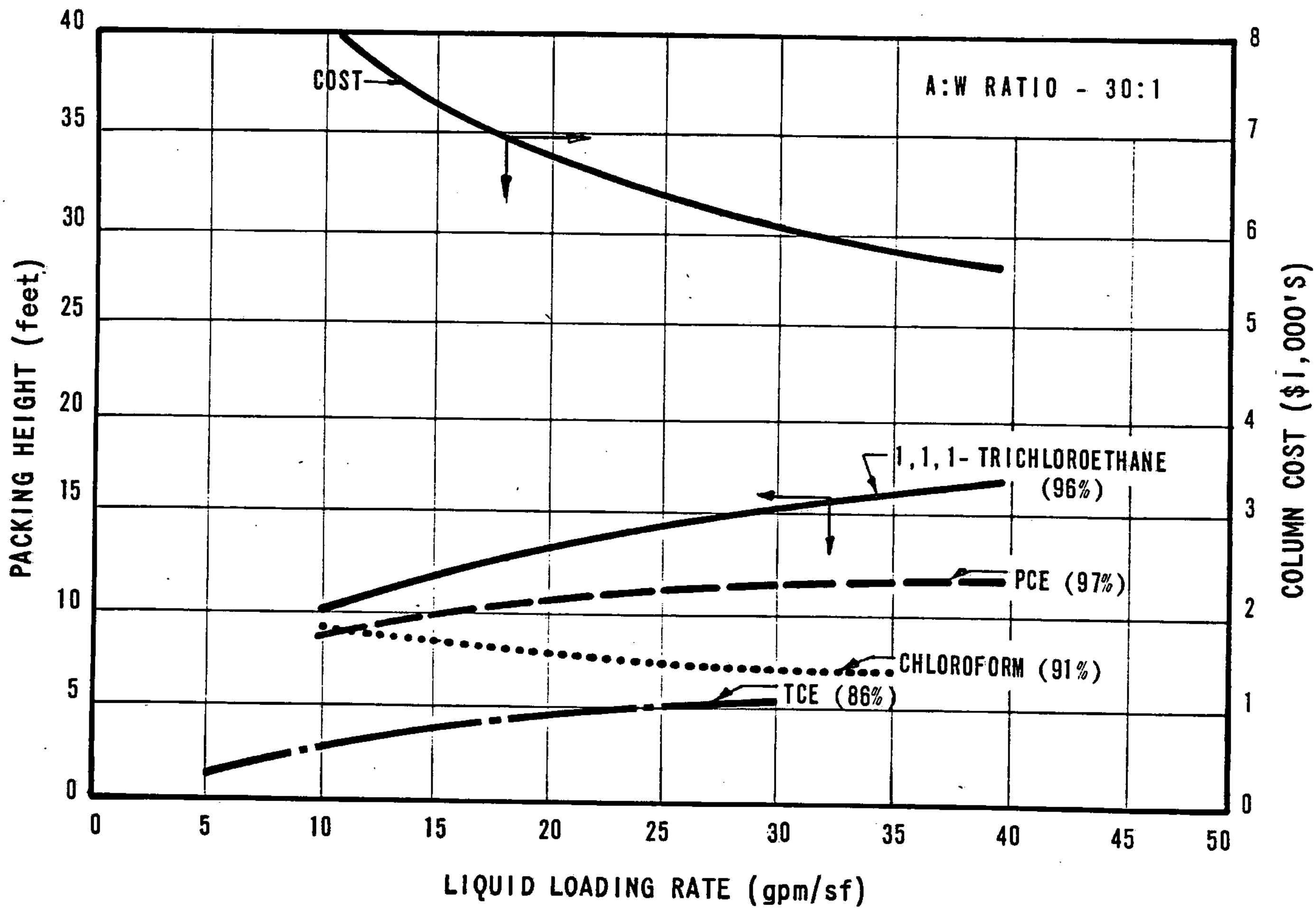
A:W Ratio - The relationship between A:W ratio and packing height is shown on Figure 12. The optimum A:W ratio was determined to be 35:1. Choosing the A:W ratio from the flat portion of the curves allows for small variations in the water flowrate and air flowrate without significantly changing the removal efficiency of the VOCs. The corresponding packing height is 15 feet.

Well No. 24

Five packed column tests were conducted at Well No. 24. The packed column influent was taken from the discharge of the well, which is currently being pumped to a nearby storm sewer.

Removal Efficiency - A summary of the results of the testing at Well No. 24 is presented in Table 15. The removal efficiency at an A:W ratio of 80:1 was greater than 90 percent for all compounds with the exception of PCE and 1,1-dichloroethane. The actual removal of PCE and 1,1-dichloroethane, however, is probably greater than indicated in Table 14. The detection limit of these compounds is 1 ug/l, and when this value is used with the low influent VOC concentrations, the computed percent removal is relatively low. The low removal efficiencies for PCE and 1,1-dichloroethane are not important, however, because of their low influent concentrations (<10 ug/l).

Mass Transfer Relationships - A plot of the mass transfer coefficient as a function of water flowrate is shown on




NOTE: (96%) DENOTES 96 PERCENT REMOVAL OF COMPOUND.

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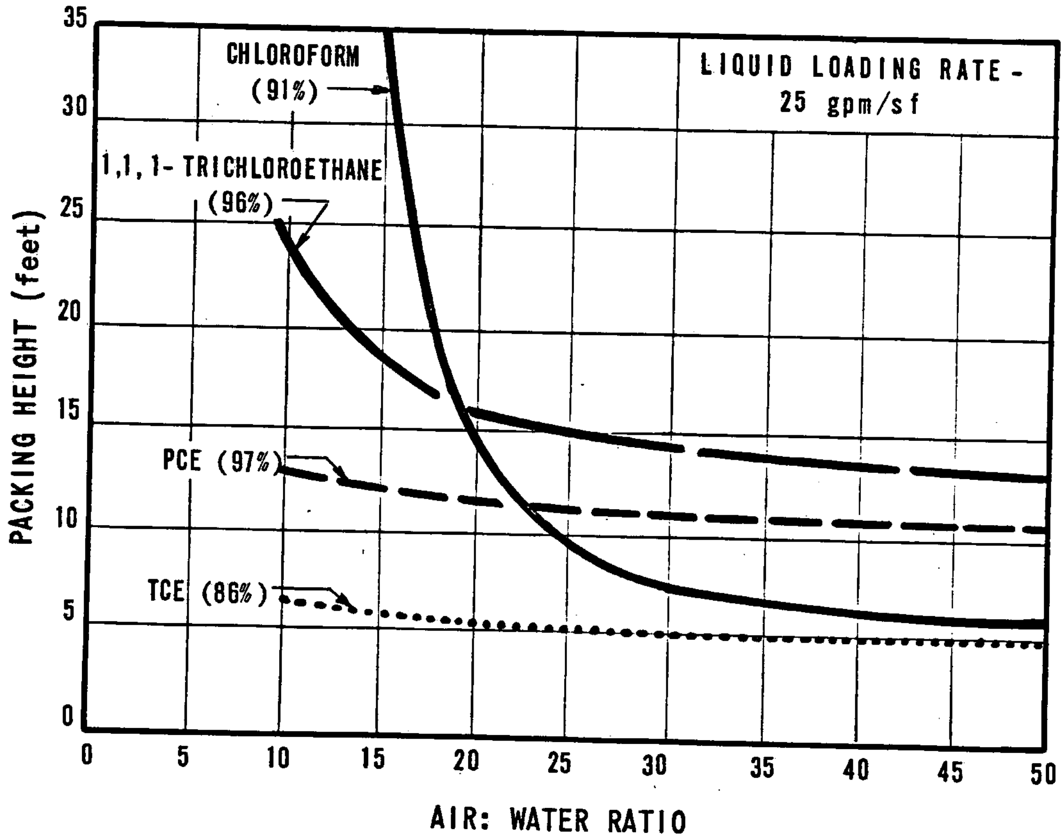
BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

LIQUID LOADING RATE vs
PACKING HEIGHT
CADMUS PLACE-MEMORIAL WELLS




NOTE: (96%) DENOTES 96 PERCENT REMOVAL OF COMPOUND.

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

A:W RATIO vs PACKING HEIGHT-
CADMUS PLACE-MEMORIAL WELLS

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TABLE 15

PILOT PACKED COLUMN AERATION
TEST RESULTS -- WELL NO. 9

| Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Packing Material | Compound | Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|---|
| 29 | 160 | 41:1 | 2-inch Tri-packs | Trichloroethylene | 7.1 | 2.1 | 70 |
| | | | | Tetrachloroethylene | 3.5 | 0.9 | 74 |
| | | | | 1,1,1-Trichloroethane | 2.9 | 0.8 | 72 |
| | | | | Chloroform | 7.0 | <1 | >86 |
| 27 | 72 | 20:1 | 2-inch Tri-packs | Trichloroethylene | 13.4 | 4 | 70 |
| | | | | Tetrachloroethylene | 6.0 | <1 | >83 |
| | | | | 1,1,1-Trichloroethane | 5.0 | 5.0 | 0 |
| | | | | Chloroform | 13.7 | 4.5 | 67 |

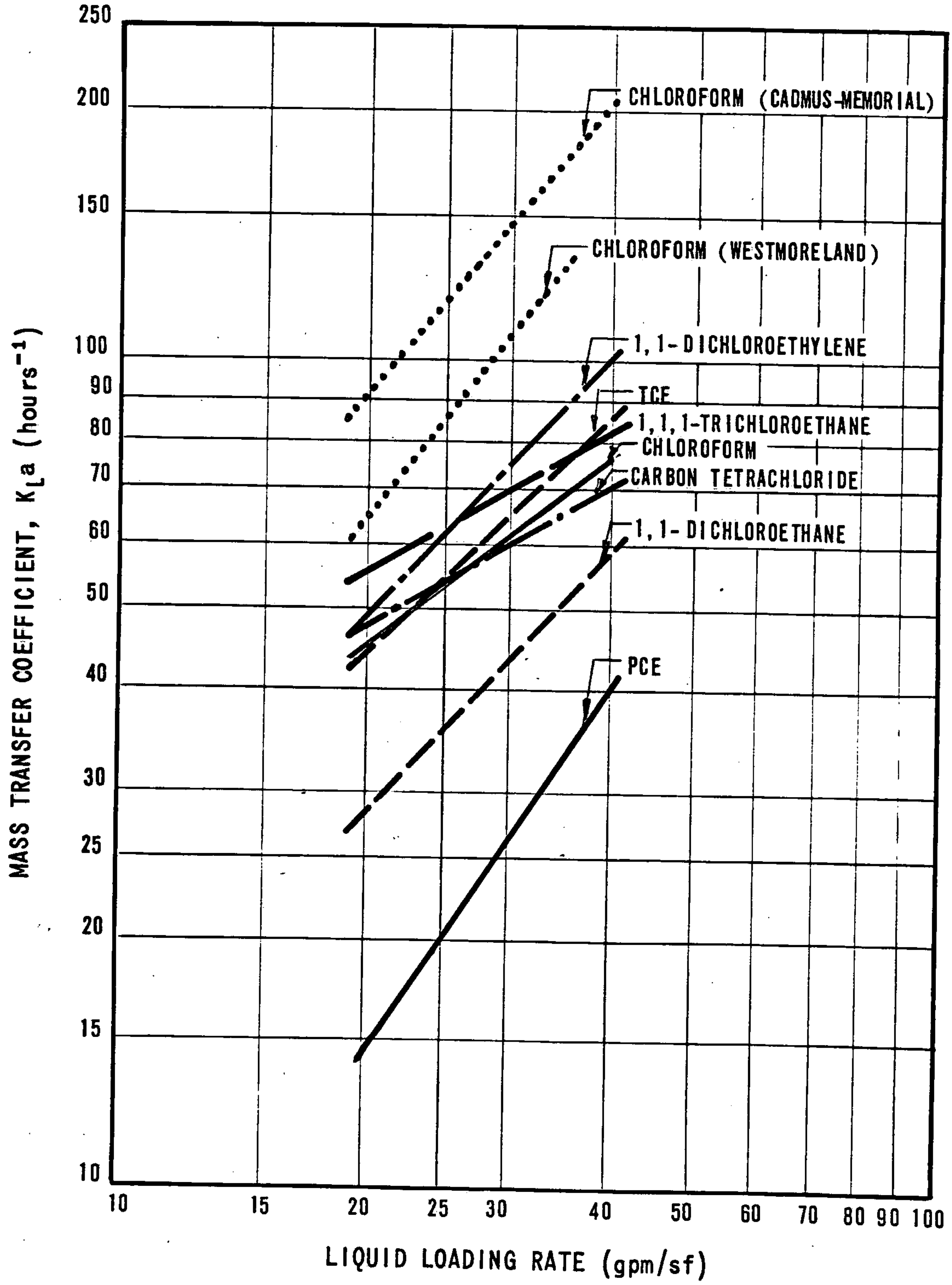
Figure 13. The compounds with the highest and lowest mass transfer coefficients were 1,1-dichloroethylene and PCE, respectively. In general, the mass transfer coefficients for all the VOCs at Well No. 24 were less than those at the other wells. For comparison, the mass transfer relationships for chloroform at the Westmoreland and Cadmus-Memorial wells are plotted on Figure 13. The mass transfer coefficient of chloroform at all water flowrates at Well No. 24 are significantly less than those for the Westmoreland and Cadmus-Memorial wells. The implication of these results is the need for a higher column at Well No. 24 compared to the other sites to achieve an equivalent chloroform removal.

The relationships between water flowrate, packing height and packed column cost are shown on Figure 14. The critical compound is chloroform. Based on the cost curve shown on Figure 14, the optimum liquid loading rate is 25 gpm/sf. As was the case at the other testing sites, packed column costs increase significantly at liquid loading rates less than 25 gpm/sf, but do not decrease appreciably at loading rates greater than 25 gpm/sf.

<u>A:W Ratio</u> - The relationship between A:W ratio and column packing height is shown on Figure 15. The optimum A:W ratio to achieve the design removal efficiencies of all the VOCs was determined to be 50:1. The corresponding packing height is 24 feet.

## Well No. 9

Four packed column tests were conducted at Well No. 9 on George Street. Electrical problems prevented all of the eight scheduled tests to be performed. As a result, only a narrow range of water flowrates and A:W ratios were evaluated. The relatively low removal efficiencies shown in Table 16 may be attributed to the low influent concentrations. The mass transfer relationships developed from these data,

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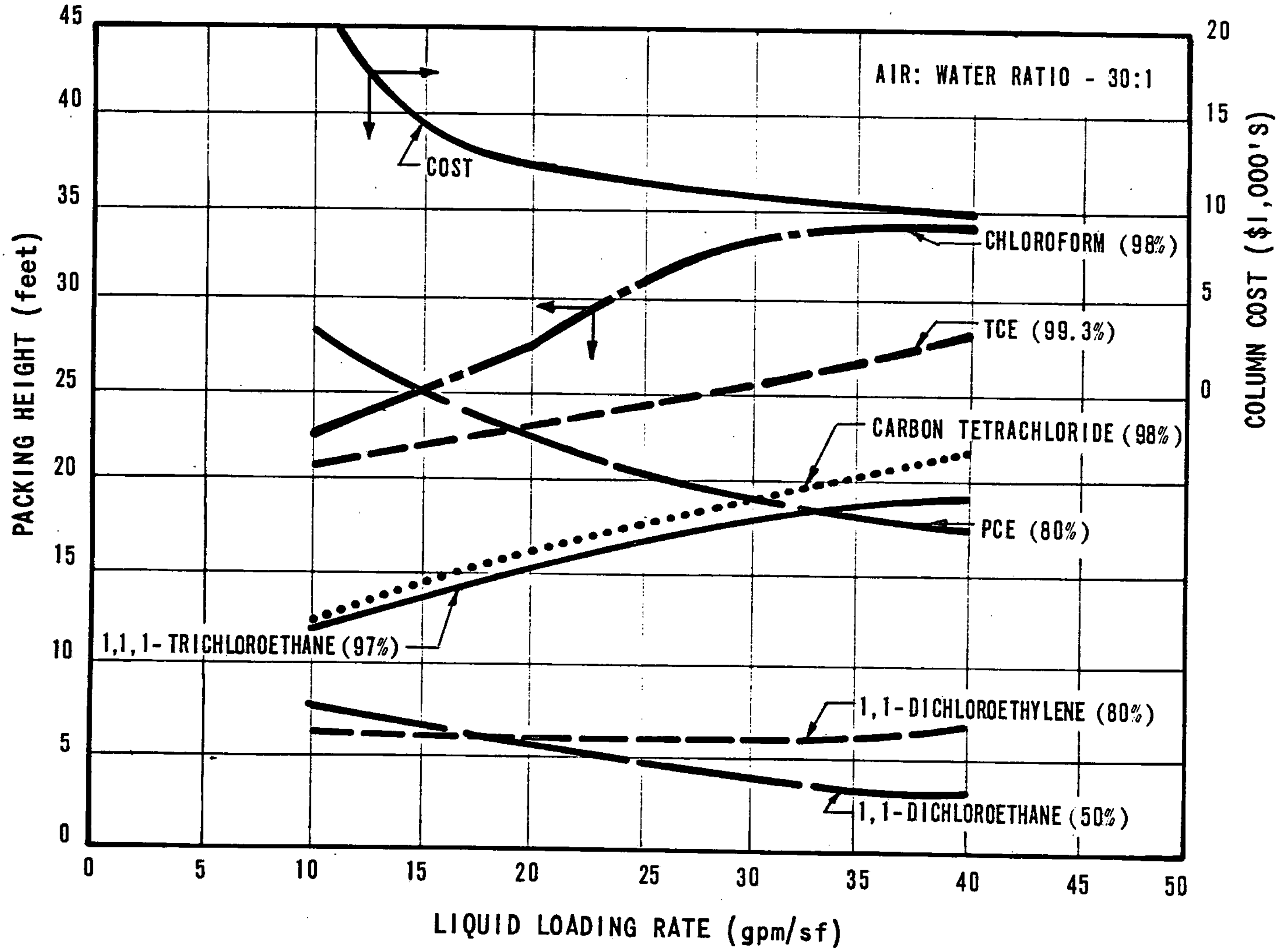
BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

MASS TRANSFER RELATIONSHIPS-
WELL NO. 24

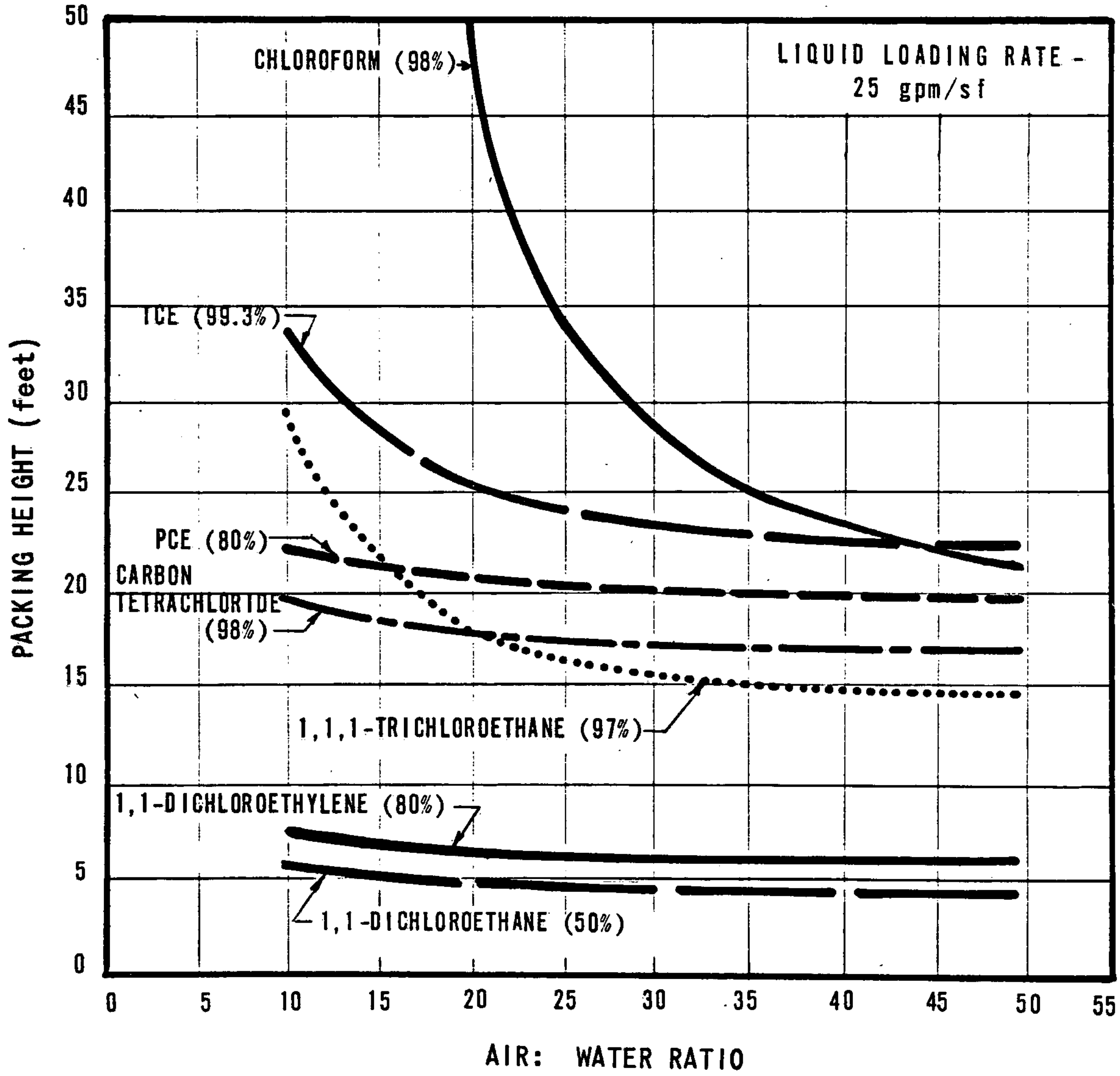



NOTE: (98%) DENOTES 98 PERCENT REMOVAL OF COMPOUND.

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

LIQUID LOADING RATE vs
PACKING HEIGHT
WELL NO. 24




NORE: (98%) DENOTES 98 PERCENT REMOVAL OF COMPOUND.

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

A:W RATIO vs PACKING HEIGHT-
WELL NO. 24

MALCOLM PIRNIE

## TABLE 16

## PILOT PACKED COLUMN AERATION TEST RESULTS -- WELL NO. 24

| Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Packing Material | Compound | Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|---|
| 15 | 160 | 80:1 | 2-inch Tri-packs | Carbon Tetrachloride | 39 | 2.3 | 94 |
| | | | | Trichloroethylene | 77 | 5.6 | 93 |
| | | | | Tetrachloroethylene | 2.2 | <1 | >55 |
| | | | | 1,1,1-Trichloroethane | 97 | 4.8 | 95 |
| | | | | Chloroform | 88 | 6.6 | 93 |
| | | | | 1,1-Dichloroethane | 4.6 | <1 | >78 |
| 27 | 72 | 20:1 | 2-inch Tri-packs | Carbon Tetrachloride | 50 | 6.2 | 88 |
| | | | | Trichloroethylene | 96 | 10 | 90 |
| | | | | Tetrachloroethylene | 2.4 | <1 | >58 |
| | | | | 1,1,1-Trichloroethane | 134 | 15 | 89 |
| | | | | Chloroform | 91 | 23 | 75 |
| | | | | 1,1-Dichloroethane | 4.7 | <1 | >79 |

however, are generally in the range of those from the other test sites. Therefore, it was decided not to conduct follow-up testing at Well No. 9, but to use the mass transfer relationships from the other wells to develop design criteria for treatment facilities at Well No. 9.

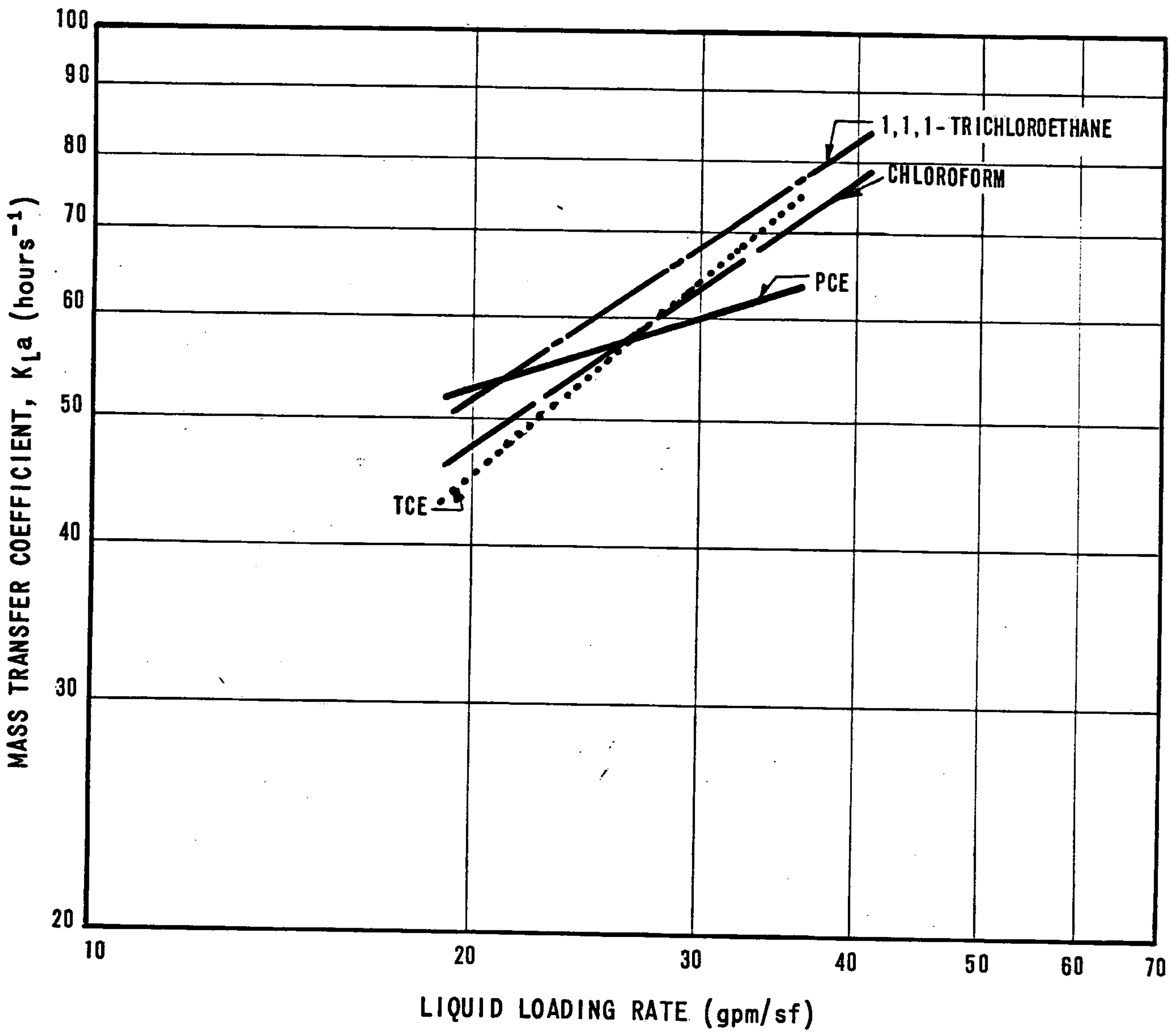
Mass Transfer Relationships - In general, the mass transfer relationships used for Well No. 9 were taken from the Westmoreland wells and Well No. 24 because they had the lowest mass transfer coefficients and, therefore, would provide for the most conservative design criteria. A plot of the relationship between water flowrate and mass transfer coefficients for the design VOCs is shown on Figure 16. Trans-1,2-dichloroethylene and 1,1,1-trichloroethane had the highest mass transfer coefficients and 1,1-dichloroethylene had the lowest. The liquid loading rate for Well No. 9 was chosen to be 25 gpm/sf on the basis of the results of the other wells.

A:W Ratio - The relationship between A:W ratio and packing height is shown on Figure 17. The optimum A:W ratio is 45:1. The corresponding packing height is 18 feet. The critical compound at Well No. 9 is PCE.

## Corrosion Tests

As previously indicated, influent and effluent samples from selected runs were analyzed for several parameters to determine the effects of aeration on the corrosivity of the treated water. The corrosivity of drinking water as a parameter is one which has both health and economic effects. Corrosive waters in a water system can add various metal contaminants to finished water which can have adverse health effects as well as produce physical deterioration of the water system itself.

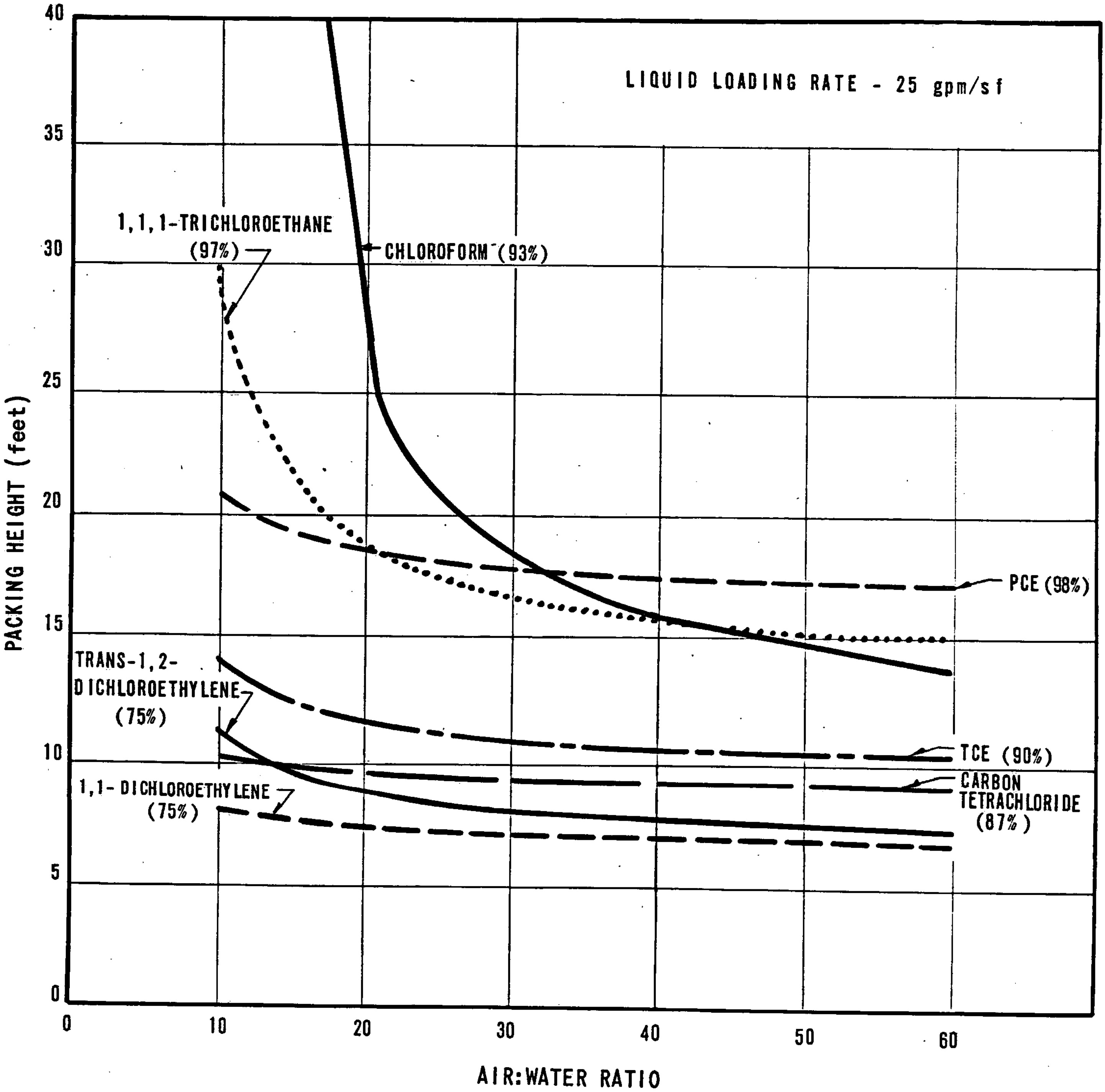
One method of determining water corrosivity is the use of the Langelier Index, which is an indicator of the calcium




MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

MASS TRANSFER RELATIONSHIPS-
WELL NO.9




NOTE: (93%) DENOTES 93 PERCENT REMOVAL OF COMPOUND.

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

A:W RATIO vs PACKING HEIGHT-
WELL NO.9

carbonate stability of the water. The Langelier Index (LI) defines the tendency of water to form or dissolve a calcium carbonate scale on the inside of the pipelines by comparing the saturation pH of calcium carbonate (pHs) with the measured pH of the water. Therefore, the Langelier Index is represented by the equation: LI = pH - pHs. Values obtained from this equation indicate the chemical stability of the water. Negative numbers resulting from the difference of pH and pHs express the tendency of the water to be corrosive, or to dissolve a calcium carbonate scale formed on the interior of the pipeline. Positive values express a state of calcium carbonate supersaturation which would indicate the formation of a protective scale of calcium carbonate on the interior surfaces of the distribution system. At a state of chemical equilibrium, the LI would result in a value of zero.

Another water quality parameter which has an effect on the corrosivity of a water supply is the dissolved oxygen (DO) concentration. The presence of DO in the distribution system can accelerate the corrosion of iron pipe. To determine the effect of aeration on the DO concentration of the Borough's water, the packed column influent and effluent were analyzed for DO.

An analysis of the data obtained from the tests conducted is summarized below:

| | Langelier Index | | Dissolved Oxygen (mg/l) | |
|---|---|---|---|---|
| | Column Influent | Column Effluent | Column Influent | Column Effluent |
| Westmoreland Wellfield | -1.57 | -0.88 | 5.5 | 12 |
| Cadmus-Memorial Wellfields | -0.72 | -0.31 | 5.5 | 11 |
| Well No. 24 | -1.30 | -0.71 | 5 | 11 |

The above results indicate that the raw water from these wells is slightly corrosive, with the Westmoreland Wellfield and Well No. 24 being more corrosive than the Cadmus-Memorial Wellfields. Aerating the water reduces the corrosiveness of the water by moving the calcium carbonate chemical stability of the water closer to equilibrium.

The DO concentration of the packed column influent at Westmoreland and Cadmus-Memorial wells and Well No. 24 were quite high, ranging from 5 to 6 mg/l. Apparently, air is being introduced into the water at the well pumps. Aeration increased the DO concentration to about 11 mg/l. The aerated samples were left open to the atmosphere for about 10 minutes, similar to that which will occur in the packed column wet well, and again analyzed for DO. The DO concentration had decreased to about 9 mg/l which is somewhat greater than the unaerated water. The unaerated water, however, is nearly saturated with DO and the increase in the DO concentration should not increase the corrosivity of the water, especially in conjunction with the greater chemical stability of the aerated water as discussed above.

Based on the results of the pilot plant testing, aeration will increase the LI of the water and slightly increase the DO concentration. Consequently, the use of an aeration process to treat the Borough wells for VOC removal should not significantly affect the corrosivity of the water.

<u>Air Pollution</u>

Some concern has been expressed for the potential contamination of the air surrounding the packed columns because the VOCs removed from the water are transferred to the air. The concentration of the compound in the air immediately exiting the column depends on the mass of the compound removed from the water and on the volume of air used in the process. Based on the projected removal of VOCs from the Borough's wells and the volume of air used in the process, a mass balance was computed for the aeration process. The results are presented in Table 17. This computation indicated the concentration of VOCs in the air immediately

# TABLE 17

## ESTIMATED VOC CONCENTRATIONS IN THE AIR AND ESTIMATED VOC EMISSION RATES

| | Average Influent Concentration (ug/l) | Percent Removal | Amount Removed (ug/l) | VOC Concentration in Air (ppm) | OSHA[1] Limit (ppm) | Emission Rate (lb/hour)[2] |
|---|---|---|---|---|---|---|
| **Westmoreland Wellfield** | | | | | | |
| Carbon Tetrachloride | 26 | 89 | 23 | 0.09 | 10 | 0.002 |
| Trichloroethylene | 68 | 94 | 64 | 0.29 | 100 | 0.005 |
| Tetrachlorethylene | 305 | 98.5 | 300 | 1.1 | 100 | 0.023 |
| Chloroform | 58 | 93 | 54 | 0.27 | 50 | 0.004 |
| Total | 457 | 96 | 441 | 1.8 | 260 | 0.034 |
| **Cadmus-Memorial Wellfields** | | | | | | |
| Carbon Tetrachloride | 2 | 82 | 2 | 0.01 | 10 | 0.001 |
| Trichloroethylene | 7 | 86 | 6 | 0.03 | 100 | 0.003 |
| Tetrachloroethylene | 23 | 97 | 22 | 0.09 | 100 | 0.011 |
| Chloroform | 4 | 91 | 4 | 0.02 | 50 | 0.002 |
| Total | 36 | 94 | 34 | 0.15 | 260 | 0.017 |
| **Well No. 9** | | | | | | |
| Carbon Tetrachloride | 15 | 87 | 13 | 0.05 | 10 | 0.001 |
| Trichloroethylene | 32 | 90 | 29 | 0.12 | 100 | 0.002 |
| Tetrachloroethylene | 11 | 98 | 11 | 0.04 | 100 | 0.001 |
| Chloroform | 24 | 93 | 22 | 0.10 | 50 | 0.001 |
| Total | 82 | 91 | 75 | 0.31 | 260 | 0.005 |
| **Well No. 24** | | | | | | |
| Carbon Tetrachloride | 169 | 98 | 166 | 0.52 | 10 | 0.009 |
| Trichloroethylene | 453 | 99.3 | 450 | 1.6 | 100 | 0.025 |
| Tetrachloroethylene | 13 | 80 | 10 | 0.03 | 100 | 0.001 |
| Chloroform | 236 | 98 | 231 | 0.93 | 50 | 0.013 |
| Total | 871 | 98 | 857 | 3.1 | 260 | 0.048 |

Notes:

1. Maximum Allowable Exposure (8-hour weighted average).
2. Based on historical average VOC levels and current well pumping rates.

(why not design RATES?

above the column under extreme removal conditions to be less than the OSHA (Occupational Safety and Health Act) limits for these chemicals. Additionally, the dispersion of the compounds in the atmosphere after they leave the column will tend to further reduce the concentration in the air.

In addition to VOC concentrations in the air surrounding the column, a mass balance was performed around the column to determine the quantity of VOCs discharged to the atmosphere. The discharge into the atmosphere of four of the VOCs detected in the Borough's ground water supply is currently regulated by NJDEP under the New Jersey Administrative Code, Title 7, Chapter 27, Subchapter 17. The four VOCs are:

- Carbon tetrachloride
- Trichloroethylene
- Tetrachloroethylene
- Chloroform

At the current pumping rates and average influent VOC concentrations at each well site, the emission rate in pounds per hour was calculated for each VOC and is shown in Table 17. As shown in the table, the discharge rate for each VOC and for total VOCs is below the NJDEP VOC air emission limit of 0.1 lb/hour. Based on the low VOC concentrations in the air and the low emission rates, contamination of the air by a packed column to remove VOCs from the Borough's wells should not be a problem, and the installation of a packed column would not be subject to the regulations of Subchapter 17.

Process Design Criteria

To apply the results of the treatability tests to the design of full-scale treatment facilities, the following process design criteria were established:

- Maximum water flowrate and loading rate
- Water temperature
- VOC identification
- Maximum influent and effluent concentrations
- Mass transfer coefficient
- A:W ratio

These design criteria then are utilized to determine the column dimensions and the air requirements.

Design criteria regarding the water flowrate and the VOC concentrations were developed previously in Chapters 2 and 3, respectively. The water temperature of the Borough wells average about 56 F, which is typical for most ground waters. The hydraulic loading rate, the mass transfer coefficient, and the A:W ratio were selected for each well based on the results of the treatability tests. These design criteria are summarized in Table 18. Design criteria for Well No. 9 were developed from the data obtained from the Westmoreland wells and Well No. 24. The hydraulic loading rate of 25 gpm/sf provided the best removals during the treatability tests.

The design criteria for the treatment facilities are based on the reduction of the critical compounds, listed in Table 18, to 10 ug/l. Therefore, the effluent concentration of the other compounds will be less than the design effluent concentration of 10 ug/l. The actual VOC removal efficiencies and effluent concentrations anticipated under design condition were determined and are presented in Table 19. In general, only the critical compounds have effluent concentrations of 10 ug/l. For the Westmoreland wells the effluent concentration of 1,1,1-trichloroethane, whose treatment requirements approach that of the critical compound, also is 10 ug/l. In general, the effluent concentration of the remaining VOCs are much less than 10 ug/l. As a consequence, the total VOC concentration in the Borough's water supply following aeration treatment, will be well below current NJDEP guidelines and probable USEPA regulations.

As indicated in Table 18, the packing height required for sufficient VOC removal varies from 15 to 24 feet. An alternative design would consist of a smaller column with a higher A:W ratio. Based on the results of the treatability

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TABLE 18

PACKED COLUMN AERATION FACILITIES
PROCESS DESIGN CRITERIA

| Location | Hydraulic Loading Rate (1) | Column Diameter (2) | Critical Compound (3) | Mass Transfer Coefficient (4) | A:W Ratio (5) | Air Flow (cfm) | Packing Height (6) |
|---|---|---|---|---|---|---|---|
| Westmoreland | 25 | 4 | Tetrachloroethylene | 56 | 40:1 | 1200 | 20 |
| Cadmus-Memorial | 25 | 9 | 1,1,1-trichloroethane | 65 | 35:1 | 6500 | 15 |
| Well No. 9 | 25 | 4 | Tetrachloroethylene | 56 | 45:1 | 1200 | 18 |
| Well Nos. 23 & 24 | 25 | 4 | Chloroform | 55 | 50:1 | 1500 | 24 |

Notes:

1. Values presented in gallons per minute per square foot.
2. Values presented in feet.
3. The critical compound requires the highest A:W ratio and packing height and is the basis for the design of the packed column.
4. Values presented in $hours^{-1}$.
5. Values presented in cubic feet:cubic feet and based on required removal of critical compound from each well.
6. Values presented in feet and based on the required removal of critical compound from each well.

TABLE 19

VOC REMOVAL AT DESIGN CONDITIONS

| | Design Percent Removal | Actual Percent Removal | Actual Effluent Concentration (ug/l) |
|---|---|---|---|
| **Westmoreland Wells** | | | |
| Carbon Tetrachloride | 89 | 97 | 3 |
| TCE | 94 | >99 | <5 |
| PCE* | 98.5 | 98.5 | 10 |
| 1,1,1-Trichloroethane | 98 | 98 | 10 |
| Chloroform | 93 | 93 | 2 |
| 1,1-Dichloroethylene | 67 | 67 | 2 |
| 1,1-Dichloroethane | 67 | 67 | 3 |
| Trans-1,2-Dichloroethylene | 80 | 83 | 9 |
| Totals | 95 | >97 | <44 ug/l |
| **Cadmus-Memorial Wells** | | | |
| Carbon Tetrachloride | 82 | 95 | 3 |
| TCE | 86 | >99 | <1 |
| PCE | 97 | 99 | 4 |
| 1,1,1-Trichloroethane* | 96 | 96 | 10 |
| Chloroform | 91 | 98 | 3 |
| Trans-1,2-Dichloroethylene | 83 | 97 | 2 |
| Totals | 93 | >97 | <23 ug/l |
| **Well No. 24** | | | |
| Carbon Tetrachloride | 98 | >99 | <5 |
| TCE | 99.3 | >99.3 | <10 |
| PCE | 80 | 83 | 9 |
| 1,1,1-Trichloroethane | 97 | >99 | <3 |
| Chloroform* | 98 | 98 | 10 |
| 1,1-Dichloroethane | 50 | 96 | 1 |
| Trans-1,2-Dichloroethylene | 97 | >99 | <4 |
| Totals | 98 | >98 | <42 ug/l |
| **Well No. 9** | | | |
| Carbon Tetrachloride | 87 | 98 | 2 |
| TCE | 90 | 98 | 2 |
| PCE* | 98 | 98 | 10 |
| 1,1,1-Trichloroethane | 97 | 98 | 7 |
| Chloroform | 93 | 96 | 6 |
| Trans-1,2-Dichloroethylene | 75 | 96 | 2 |
| 1,1-Dichloroethylene | 75 | 96 | 2 |
| Totals | 94 | 98 | 27 ug/l |

*Denotes critical compound.

tests as indicated previously on the plots of A:W ratio versus packing height, a 10-foot reduction in the column height would require a four-fold increase in the A:W ratio. A reduction in the column height would not necessarily reduce the initial cost of the project because the need for larger blowers would tend to offset the lower cost for the column and the packing material. Also, such a large increase in the air flowrate would require a larger column diameter to reduce friction losses through the column to maintain the design removal efficiency. Any increase in the column diameter would tend to further offset savings from constructing a smaller column and may even result in a higher initial cost. More importantly, a four-fold increase in the A:W ratio would result in almost a four-fold increase in the power requirements for operating the facility. This increase in the operating costs would more than offset the savings, if any, in the initial cost of the project. Therefore, the selected design criteria offer the optimum design in terms of equivalent annual costs. These design criteria were used to determine preliminary sizes and costs of treatment facilities which are described in Chapter 8.

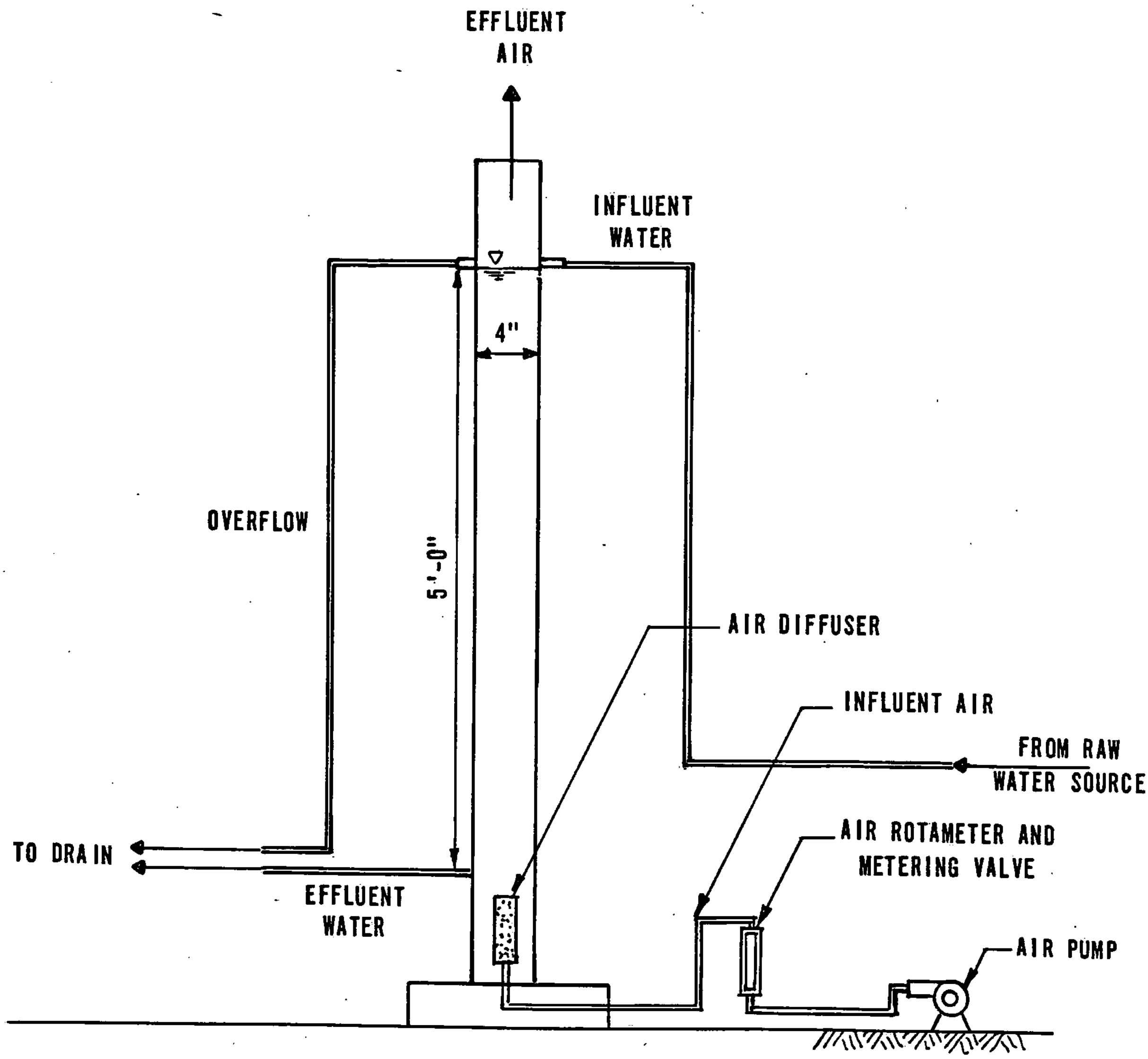
# 6. DIFFUSED AERATION TREATABILITY TESTING PROGRAM

In addition to the packed column aeration tests, diffused aeration treatability tests were conducted at the Westmoreland and Cadmus Place Wellfields. The purpose of the tests was to evaluate the effectiveness of the diffused aeration process for VOC removal at these wellfields. The treatability tests simulated the use of diffused aeration in the existing ground-level storage tanks at each wellfield. A description of the pilot tests and an evaluation of the test results are presented in this chapter.

## Description of Testing Equipment

The treatability tests were conducted using a pilot-scale diffused aeration column, which has been designed and fabricated by Malcolm Pirnie. The pilot column consists of influent piping, the column, an air pump, and air rotameter and metering valve. A diagram of the pilot column is shown on Figure 18. Operation of the column is countercurrent. Raw water is pumped from the well to the top of the column, flows down through the column and is discharged through a control valve at the bottom of the column. Water flow was monitored with a stopwatch and graduated cylinder. Air is forced by an air pump through a control valve and rotameter to a air stone diffuser in the bottom of the column. The bubbles produced by the diffuser rise through the water and then pass into the atmosphere. Sample taps are provided at the top and bottom of the column for collecting raw and treated water samples.

The column is 4 inches in diameter and is constructed of acrylic pipe. The height of the water column is 5 feet, and the volume is 1.75 cubic feet. The air pump has a range of 0 to 1.5 cubic feet per hour.

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

DIAGRAM OF PILOT DIFFUSED
AERATION COLUMN

## Description of Treatability Tests

The diffused aeration treatability tests were designed to simulate the use of static aerators in the ground-level storage tanks at the Westmoreland and Cadmus Place Wellfields. The design factors affecting the rate of VOC removal by diffused aeration are similar to those factors listed for packed column aeration in Chapter 5. The design factors which were varied during the pilot diffused aeration tests were the air flowrate and A:W ratio.

At each of the wellfields tested, the pilot column was set up and operated at several A:W ratios. For each run, the air flowrates were adjusted to yield the desired A:W ratio. The water flowrate was fixed by the detention time anticipated in the storage tanks at the design well flowrates. In addition, it was assumed that only two-thirds of the reservoir would be used for aeration. On this basis, the detention time in the Westmoreland storage tank is about 74 hours. The treatability tests for the Westmoreland wells, however, were conducted with a detention time of 24 hours and the results were extrapolated to determine design criteria. At Cadmus Place, the detention time is estimated to be 9 hours. The detention time for the treatability tests at Cadmus Place was also 9 hours. The column was then operated for the required detention time and samples of raw and treated water were collected.

## Results of Testing Program

The results of the diffused aeration tests are shown in Tables 20 and 21 for the Westmoreland and Cadmus-Memorial Wellfields, respectively. Because of the similarity of the results from both of the testing sites, the data were combined and are shown graphically on Figure 19. In general, the results indicate the following:

1. Increasing the A:W ratio results in an increase in the removal efficiency of the VOCs.

TABLE 20

RESULTS OF DIFFUSED AERATION TREATABILITY[1] TESTS -- WESTMORELAND WELLFIELD

| | A:W Ratio | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1:1 | | | 5:1 | | | 10:1 | | |
| | Inf.[2] | Eff.[3] | %[4] | Inf. | Eff. | % | Inf. | Eff. | % |
| TCE | 47 | 38 | 19 | 39 | 40 | 0 | 51 | 37 | 28 |
| PCE | 253 | 196 | 23 | 246 | 130 | 47 | 310 | 159 | 49 |
| 1,1,1-Trichloroethane | 118 | 122 | 0 | 113 | 83 | 27 | 123 | 88 | 29 |
| Chloroform | 29 | 48 | 0 | 46 | 36 | 22 | 28 | 18 | 35 |
| 1,1-Dichloroethylene | 17 | 20 | 0 | 22 | 2 | 91 | 31 | 7 | 77 |
| 1,1-Dichloroethane | 8 | 11 | 0 | 10 | <1 | >90 | 10 | 2 | 80 |
| Trans-1,2-Dichloroethylene | 40 | <1 | >98 | - | - | - | 44 | 18 | 59 |
| 1,2-Dichloroethane | 22 | 32 | 0 | 30 | <1 | >97 | 13 | <1 | >92 |

Notes:

1. Operation Conditions:

   - Influent Water Temperature: 60 F
   - Effluent Water Temperature: 70 F
   - Detention Time: 24 hours

2. Influent concentration, ug/l.
3. Effluent concentration, ug/l.
4. Percent removal.

TABLE 21

RESULTS OF DIFFUSED AERATION TREATABILITY TESTS CADMUS-MEMORIAL WELLFIELDS (1)

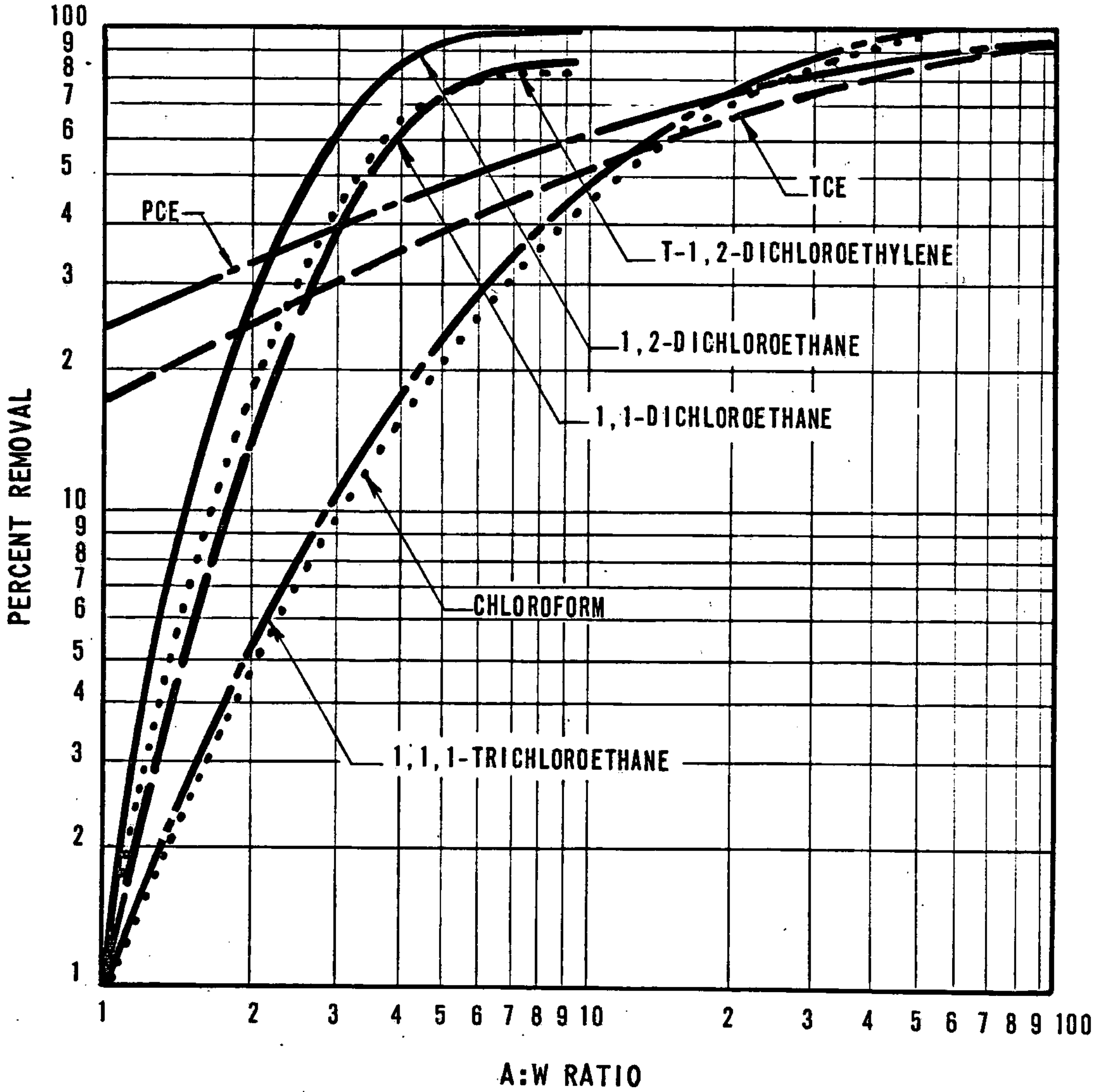
| | Test No. 1 | | | Test No. 2 | | |
|---|---|---|---|---|---|---|
| | Inf. (2) | Eff. (3) | % (4) | Inf. | Eff. | % |
| Carbon Tetrachloride | 1.6 | 0.4 | 75 | 2.0 | 0.5 | 75 |
| TCE | 3.9 | 1.8 | 54 | 6.0 | 1.9 | 68 |
| PCE | 13 | 5.4 | 59 | 17 | 6.0 | 65 |
| 1,1,1-Trichloroethane | 1.5 | 0.3 | 80 | 2.4 | 0.3 | 88 |
| Chloroform | 18 | 19 | 0 | 19 | 14 | 26 |
| Trans-1,2-Dichloroethylene | 16 | 10 | 38 | 28 | 11 | 61 |

Notes:

1. Operation Conditions:

   - A:W Ratio: 30:1
   - Influent Water Temperature: 60 F
   - Effluent Water Temperature: 65 F
   - Detention Time: 9 hours

2. Influent concentration, ug/l.
3. Effluent concentration, ug/l.
4. Percent removal.

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

RESULTS OF DIFFUSED AERATION TESTS

2. At equal A:W ratios, diffused aeration is less effective than packed column aeration for VOC removal.

As shown on Figure 19, 1,2-dichloroethane is the most easily removed compound. At removal efficiencies less than 50 percent, chloroform is the most difficult compound to remove, while at removal efficiencies greater than 50 percent, TCE is the most difficult to remove.

<u>A:W Ratio</u> - For the Westmoreland Wellfield, the design percent removals for chloroform and TCE, as determined in Chapter 3, are 67 and 94 percent, respectively. For the Cadmus-Memorial Wellfields, the design percent removals for chloroform and TCE are 86 and 91 percent, respectively. Therefore, the critical compound at both sites is TCE. Projecting the test results from Figure 19, the required A:W ratio at each site is about 100:1. This is significantly greater than that required for equivalent treatment with packed column aeration.

Pilot-scale diffused aeration processes are generally less efficient, however, than full-scale processes and the required A:W ratio for full-scale facilities will be less than indicated by the treatability tests. Two factors affecting the A:W ratio are: depth of water and bubble characteristics. The depth of water in the ground-level storage tanks at the Westmoreland and Cadmus-Memorial Wellfields are 25 feet and 15 feet, respectively. The water depth of pilot column, however, was 5 feet. The time required for the air bubbles to rise to the surface in the storage tanks will be greater than that in the pilot column. Therefore, the time of contact between air and water in the reservoirs will be greater than in the pilot tests producing higher VOC removal efficiencies.

The second factor affecting the A:W ratio is bubble characteristics. The diffusers which would be used in full-scale facilities will produce smaller bubbles than was possible with the pilot-scale column. Smaller air bubbles increase the amount of interfacial area available for the transfer of VOCs and, hence, increase removal efficiency.

The combined effect of greater contact time and improved bubble characteristics will be to increase the VOC removal efficiency of the diffused aeration process and decrease the required A:W ratio. The reduction in A:W ratio due to the above factors in scaling up from pilot to full-scale facilities is estimated to be about 50 percent. Thus, the required A:W ratio for diffused aeration at both the Westmoreland and Cadmus-Memorial Wellfields is about 50:1.

Process Design Criteria

To apply the results of the treatability tests to the design of a full-scale treatment facility, the following process design criteria were established:

- Maximum water flowrate
- Water temperature
- VOC identification
- Maximum influent and effluent concentrations
- A:W ratio

Design criteria regarding the water flowrate and the VOC concentrations were developed previously in Chapters 2 and 3, respectively. The water temperature, as stated previously, averages about 56 F. The applicable design criteria for diffused aeration are summarized in Table 21.

As indicated in Table 22, the required air flowrates for the Westmoreland and Cadmus-Memorial Wellfields are 1,500 cfm and 9,000 cfm, respectively. The number of static aerators required for Westmoreland and Cadmus-Memorial are 60 and 360, respectively. The number of aerators is based on 25 cfm per aerator. These design criteria were used to determine preliminary sizes and costs of treatment facilities, which are described in the following chapter.

TABLE 22

DIFFUSED AERATION FACILITIES
PROCESS DESIGN CRITERIA

| Location | Detention Time (hrs)[1] | A:W Ratio | Air Flow (cfm) | No. of Diffusers[2] |
|---|---|---|---|---|
| Westmoreland | 74 | 50:1 | 1,500 | 60 |
| Cadmus-Memorial | 9 | 50:1 | 9,000 | 360 |

Notes:

1. Based on utilization of 67 percent of ground-level storage tank capacity.
2. Based on the use of static aerators.

# 7. GRANULAR ACTIVATED CARBON TREATABILITY TESTING PROGRAM

The third process which was evaluated for the removal of VOCs in the Borough's ground water supply was granular activated carbon (GAC). Pilot-scale tests were conducted on samples of raw water from the Westmoreland and Cadmus-Memorial Wellfields and Well No. 24. Preliminary analyses of the results from these tests indicated that it was not necessary to evaluate the use of GAC at Well No. 9 because of high carbon usage rates at the other wells. A description of the pilot tests and an evaluation of the test results are presented in this chapter.

## Description of Testing Equipment

The treatability tests were conducted using a dynamic mini-column adsorption system. The mini-column system, which was designed and fabricated by Malcolm Pirnie, consists of a glass sample container, a chemical metering pump, teflon and stainless steel GAC mini-column (3.2 mm inside diameter x 15 cm long). A schematic diagram of the mini-column system is presented on Figure 20. The materials used in the mini-column system which are in contact with the water samples are composed of glass, teflon, or stainless steel. These inert materials are used to avoid sample contamination. Water is pumped from the sample reservoir through a filter to remove suspended solids and oils which could damage the pump. The pump discharges to a 1/4 inch inside diameter stainless steel tube which conveys the water to the mini-carbon column. The mini-column influent line includes a 300 ml cylinder to dampen flow pulsations and a pressure gage to monitor system pressure. Following the pulsation dampener and pressure gage, the water is pumped through the mini-column. The column holds 0.10 gram of

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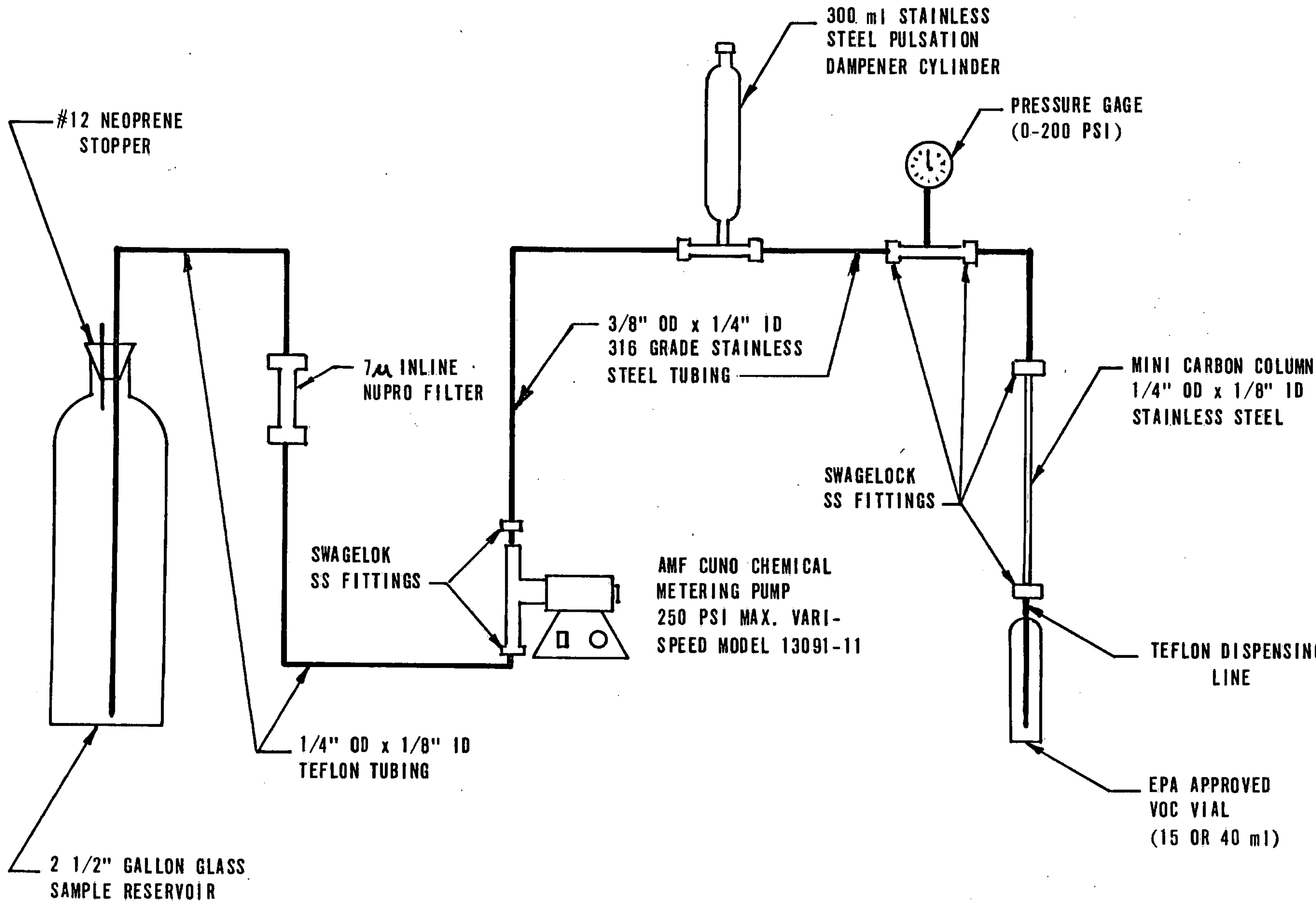



CARBON MINI-COLUMN SYSTEM

MINI-COLUMN SYSTEM
SCHEMATIC OF GAC
AT AFFECTED BOROUGH WELLS
ORGANIC CHEMICAL TREATMENT FACILITIES
BOROUGH OF FAIR LAWN, NEW JERSEY

FIGURE 20

100 x 200 mesh ground GAC which has been heat treated to remove any adsorbed contaminants. Following compaction via vibration, the depth of GAC bed is about 1 inch. The GAC is held in place with 1/2 inch of glass wool packed into the bottom of the column. The mini-column effluent is conveyed to a sample vial via teflon tubing. The teflon effluent line discharges below the liquid surface in the sample vial to minimize volatilization of the VOCs contained in the mini-column effluent.

Description of Treatability Tests

The removal of a volatile organic compound by GAC adsorption depends on several factors:

- Type of GAC
- Temperature of the water
- Chemistry of the compound

The latter two factors were constant and were not varied during the tests of the Borough wells to optimize the process. The design factor which was varied during the tests was the type of GAC.

Two types of GAC were evaluated during testing of water from the Westmoreland Wellfield: Carborundum GAC 830 and Calgon Filtrasorb 300. Based on the results of these tests the best GAC was then used for testing at the Cadmus-Memorial Wellfields and Well No. 24.

At each of the wells tested, representative samples of raw water were obtained and shipped to the Malcolm Pirnie laboratory at White Plains, New York. For each mini-column test, the column was operated for 8 to 10 hours and samples of the column effluent were taken periodically. The samples were then analyzed for VOCs to determine the concentration of the various compounds.

Performance criteria for GAC adsorption were established at each testing site so that adsorption and aeration could be compared on an equal basis. An equal comparison of the processes requires that the GAC effluent contain total VOC concentrations less than or equal to those for aeration at design conditions. Therefore, the carbon usage rate and carbon life for each testing site are based on meeting the total effluent VOC concentration of the aeration systems at design conditions. The concentrations for each testing site are summarized below:

| | Total Effluent VOC Concentration (ug/l) |
|---|---|
| Westmoreland | <44 |
| Cadmus-Memorial | <23 |
| Well No. 24 | <42 |

Results of Testing Program

The results of the dynamic mini-column adsorption tests generally indicate the following:

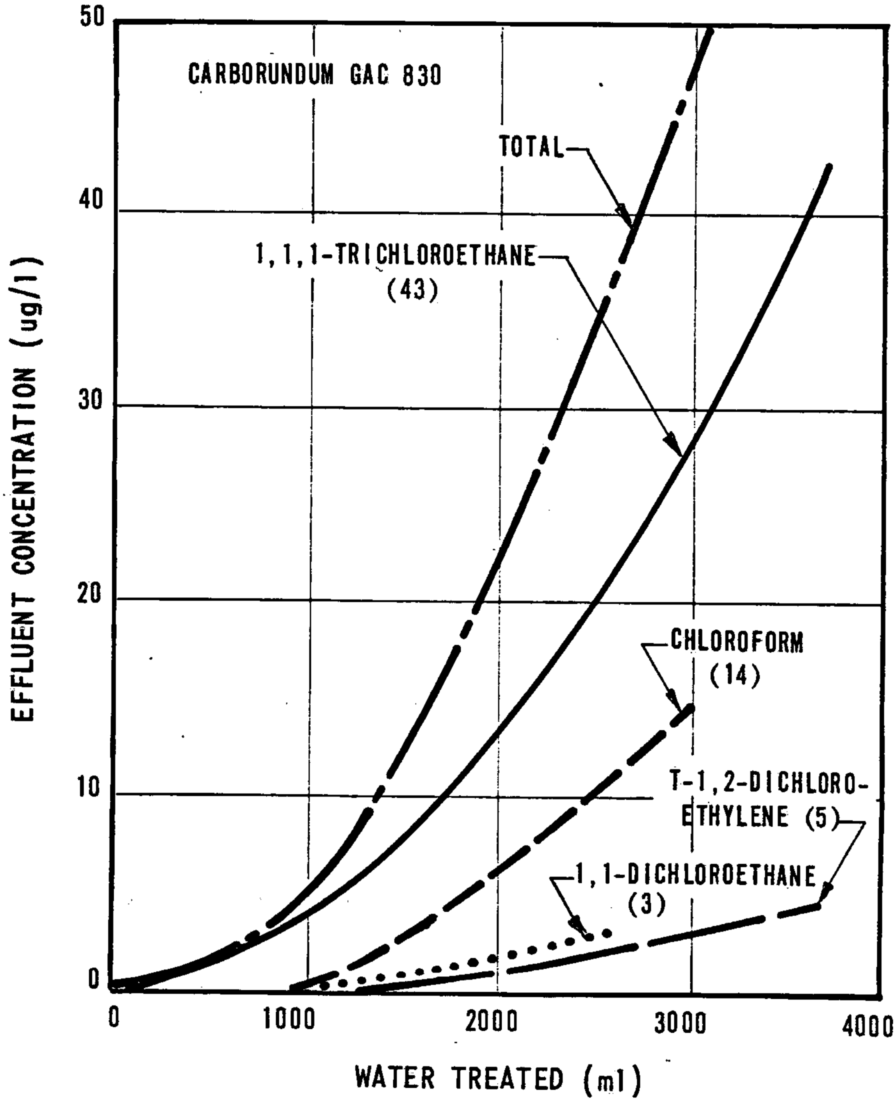
1. High removal VOC efficiencies can be obtained at each testing site through the use of GAC adsorption up until the time of compound breakthrough. Using the Westmoreland water, 1,1,1-trichloroethane broke through first, while trans-1,2-dichloroethylene and chloroform broke through first using the Cadmus-Memorial and the Well No. 24 water. At Well No. 24, trans-1,2-dichloroethylene was the most difficult to remove.

2. Carborundum GAC 830 has a longer life than Calgon Filtrasorb 300 based on the results of testing for the Westmoreland Wellfield and was used for testing for the Cadmus-Memorial Wellfields and Well No. 24.

3. Estimated carbon life under current and design influent concentrations is very short and is generally less than 100 days.

Each of these conclusions is expanded upon in the following sections.

Breakthrough Characteristics - The results of the mini-column tests using water from Westmoreland are shown graphically on Figures 21 and 22. As shown on these figures,




NOTE: (43) DENOTES INFLUENT VOC CONCENTRATION (μg/l).

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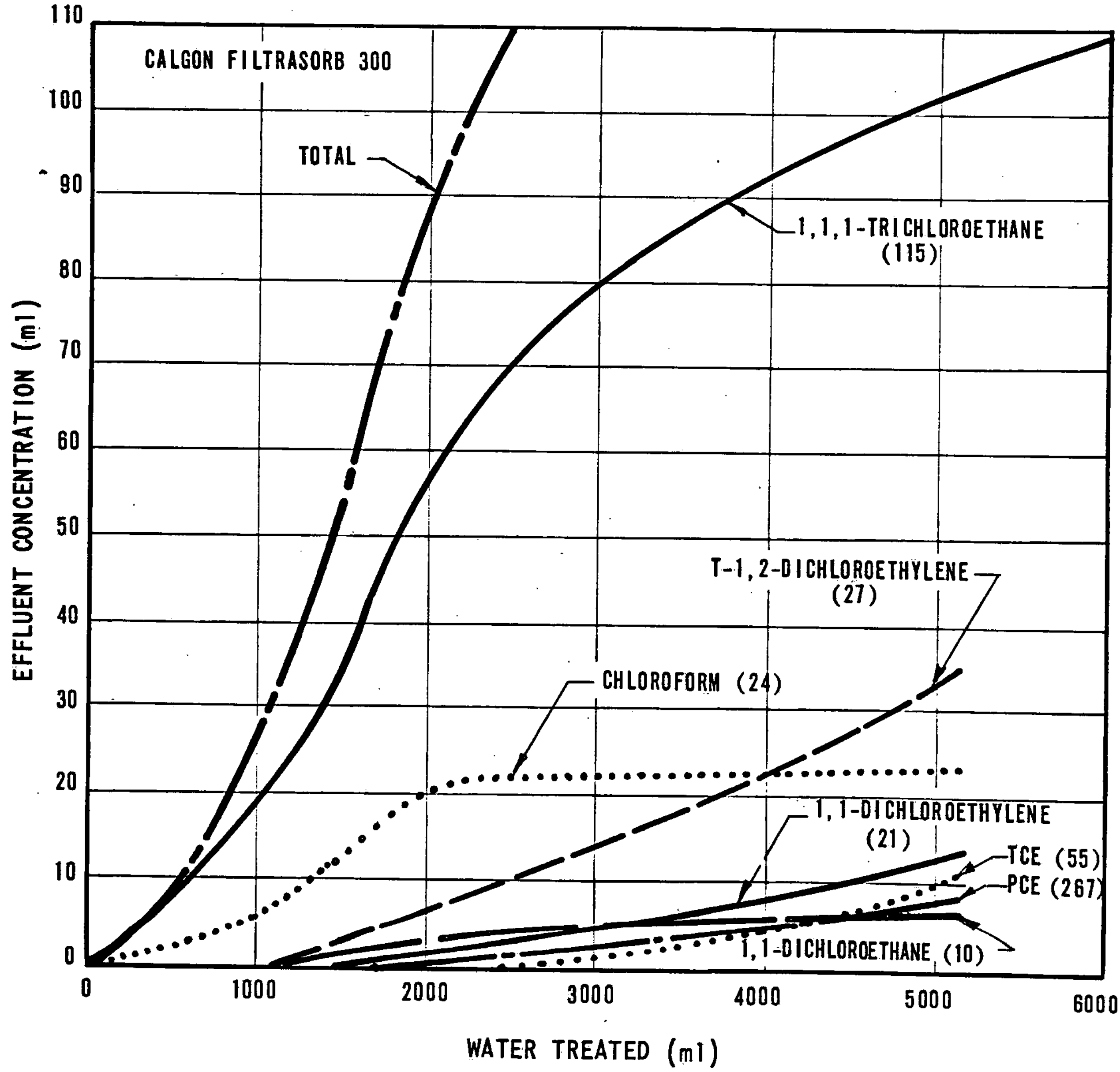
BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES AT AFFECTED BOROUGH WELLS

RESULTS OF MINI-COLUMN ADSORPTION TEST-WESTMORELAND WELLS




NOTE: (115) DENOTES INFLUENT VOC CONCENTRATION (µg/l).

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BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

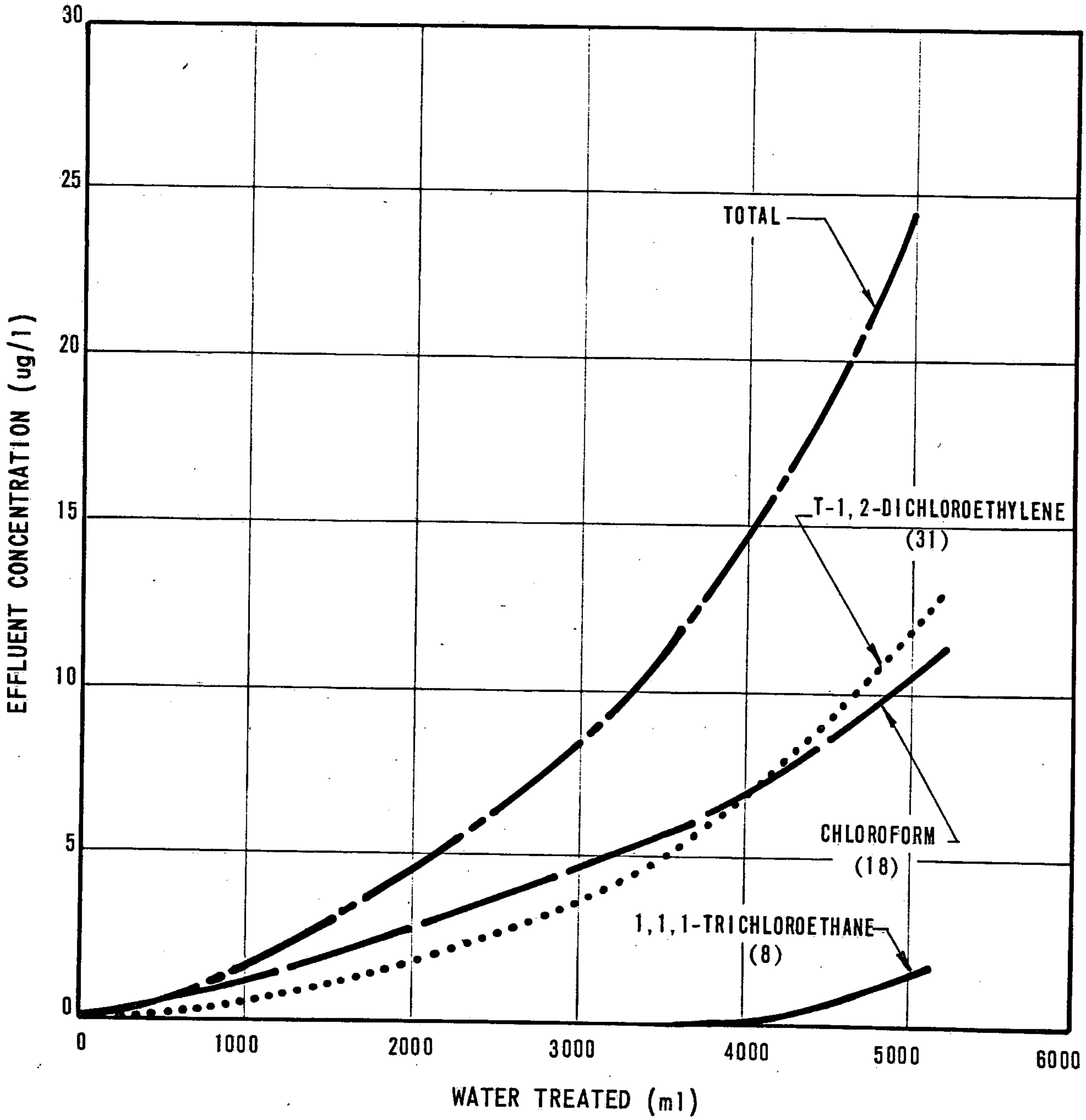
RESULTS OF MINI-COLUMN ADSORPTION TESTS-
WESTMORELAND WELLS

1,1,1-trichloroethane broke through almost immediately for both of the carbons tested. Chloroform was the next compound to break through, followed by trans-1,2-dichloroethylene and 1,1-dichloroethane.

The results of the mini-column tests using water from the Cadmus-Memorial Wellfield are shown graphically on Figure 23. The first compound to break through was chloroform, followed very closely by trans-1,2-dichloroethylene. 1,1,1-trichloroethane was very slow to break through compared to the results using the Westmoreland water, probably because of the lower concentration of this compound in the Cadmus-Memorial water.

The results of the mini-column tests using water from Well No. 24 are shown graphically on Figure 24. As shown on the figure, chloroform was the first to break through, followed very closely by 1,1,1-trichloroethane and trans-1,2-dichloroethylene. Because of the higher concentrations of all of these compounds in the Well No. 24 water, breakthrough was much faster compared to that which occurred using the Westmoreland and Cadmus-Memorial waters.

<u>Comparison of Carbons</u> - At the Westmoreland Wellfield, two types of GAC were evaluated: Carborundum GAC 830 and Calgon Filtrasorb 300. The performance of each GAC is compared on Figure 25. For both types of GAC, 1,1,1-trichloroethane and chloroform were the first compounds to appear in the effluent. As shown on Figure 25, the carbon life for the Carborundum GAC is significantly greater than with the Calgon GAC. At both current and design VOC concentrations, the carbon life for the Carborundum GAC is about 80 percent greater than that for the Calgon GAC. Based on the results of the mini-column tests for the Westmoreland Wellfield, the Carborundum GAC was determined to be optimum and was used for the mini-column testing at the other sites.

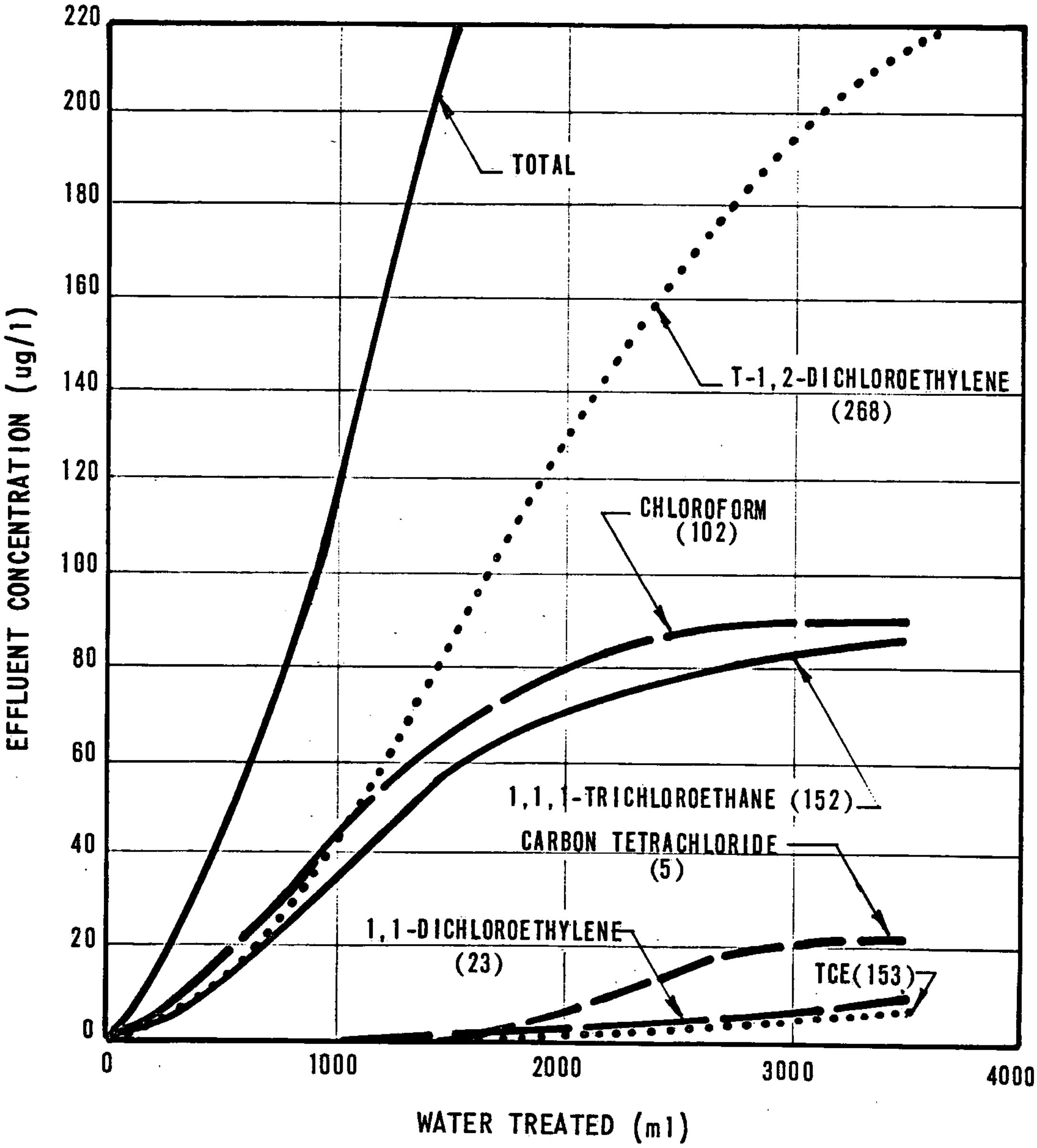



NOTE: (31) DENOTES INFLUENT VOC CONCENTRATION (ug/l).

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

RESULTS OF MINI-COLUMN ADSORPTION TEST-
CADMUS PLACE - MEMORIAL WELLS



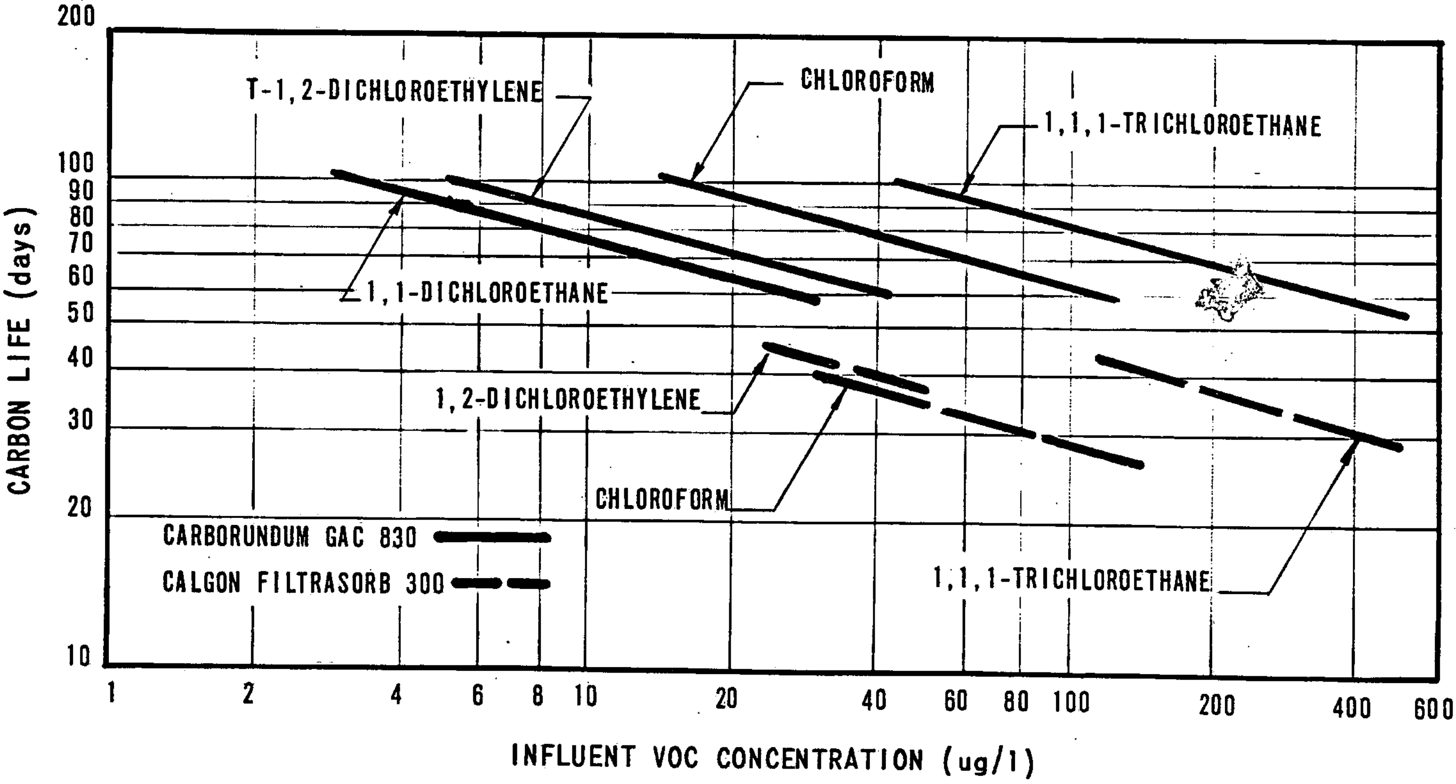

NOTE: (268) DENOTES INFLUENT VOC CONCENTRATION (µg/l).

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY

ORGANIC CHEMICAL TREATMENT FACILITIES AT AFFECTED BOROUGH WELLS

RESULTS OF MINI-COLUMN ADSORPTION TEST - WELL NO. 24



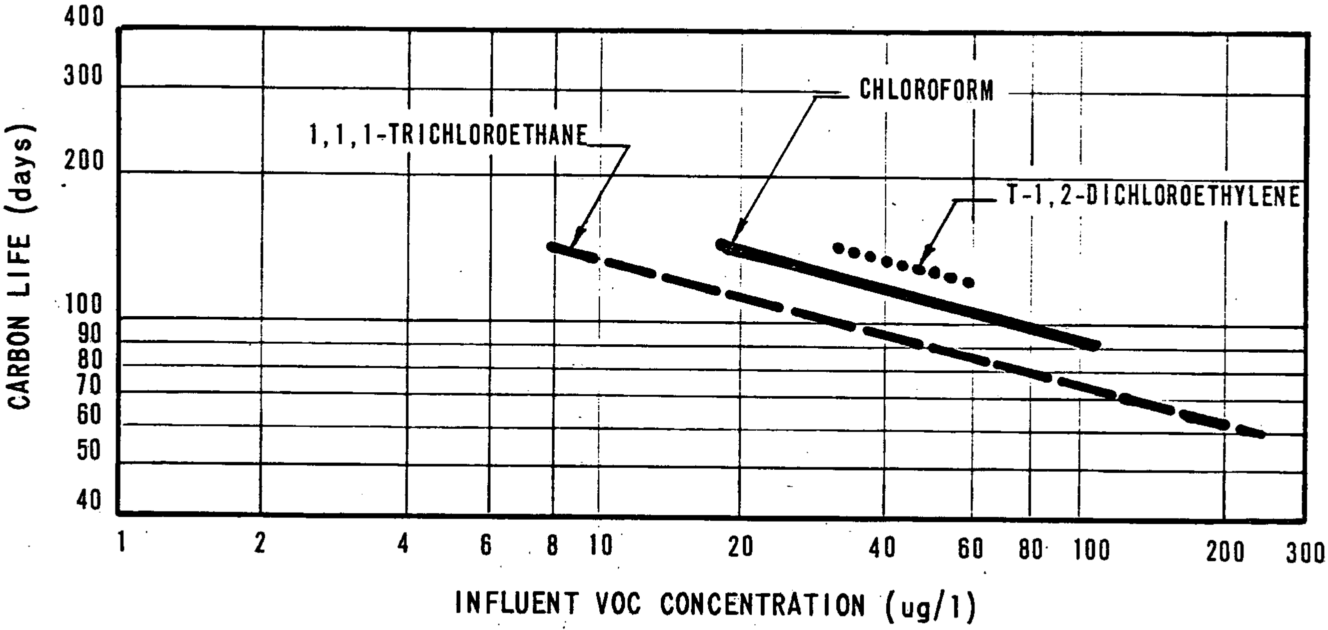

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

INFLUENT VOC CONCENTRATION
vs CARBON LIFE
WESTMORELAND WELLS

Carbon Life - Based on the results of the mini-column adsorption tests, carbon usage rates were established for each testing site. The carbon usage rates are based on the performance criteria presented in the previous section. These usage rates were then used to determine the carbon life at each testing site. The carbon life is the time a given amount of carbon can be used before it must be replaced or regenerated. The carbon life, however, depends on the level of VOCs in the water being treated. The design VOC concentrations, established in Chapter 3, are generally higher than the VOC concentrations which were present in the raw water samples used for the mini-column tests. As a result, the mini-column data had to be extrapolated to estimate carbon life at the design VOC concentrations. The results of this analysis are shown graphically on Figures 25, 26 and 27, for the Westmoreland and Cadmus-Memorial Wellfields and Well No. 24, respectively. These plots show the estimated carbon life at both current and design VOC concentrations. For the Westmoreland Wellfield, the carbon life is estimated to be 80 days under current water quality conditions and 56 days under design conditions.

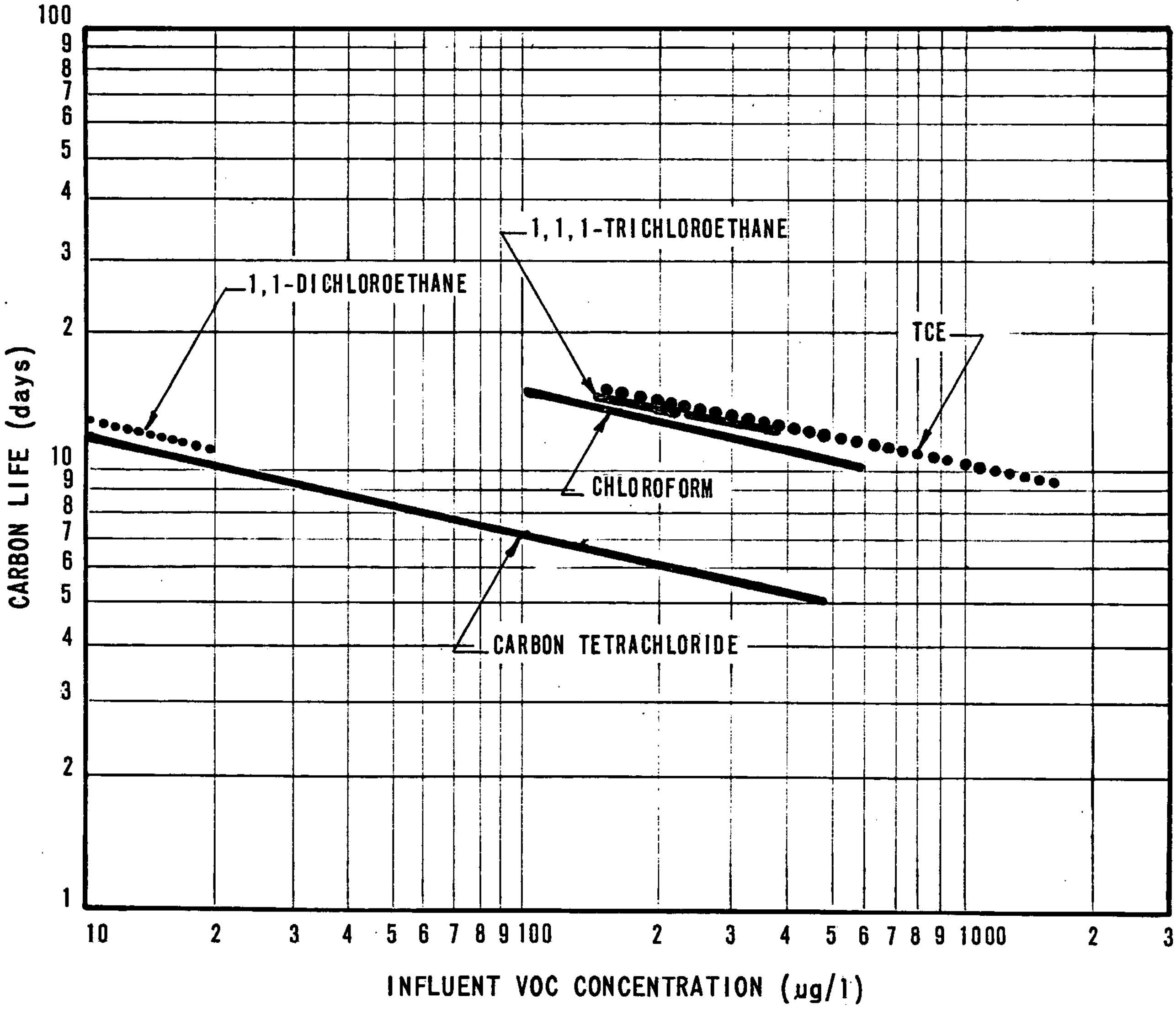
The results of the mini-column tests for the Cadmus-Memorial Wellfields, indicated that trans-1,2-dichloroethylene and chloroform were the first compounds to break through. 1,1,1-Trichloroethane did not appear in the mini-column effluent until much later in the test. However, when the carbon life was determined from the mini-column test and extrapolated to determine carbon life at design VOC concentrations, as shown on Figure 26, 1,1,1-trichloroethane became the critical compound. The critical compound for GAC is that compound which has the shortest carbon life. The concentration of 1,1,1-trichloroethane in the mini-column sample was relatively low. As a result, its presence in the effluent was insignificant. The design 1,1,1-trichloroethane




BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

INFLUENT VOC CONCENTRATION
VS CARBON LIFE
CADMUS PLACE-MEMORIAL PARK WELLS

MALCOLM PIRNIE




BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

INFLUENT VOC CONCENTRATION
vs CARBON LIFE
WELL NO. 24

MALCOLM PIRNIE

concentration, however, is relatively high, comprising 30 percent of the total VOC concentration. This caused the carbon life for 1,1,1-trichloroethane at design conditions to decrease disproportionately when compared to the other compounds. As a result, 1,1,1-trichloroethane becomes the critical compound at design conditions. Carbon life for the Cadmus Place-Memorial Park wells at current VOC concentrations is estimated to be 140 days. At design conditions, carbon life is estimated to be about 70 days.

Well No. 24 has the highest VOC concentrations and, as a result, the highest carbon usage rate. The estimated carbon life at Well No. 24 is shown on Figure 27. Under current water quality conditions, the carbon life is estimated to be 15 days. At design conditions, carbon tetrachloride is the critical compound and the carbon life will be about 5 days.

Process Design Criteria

To apply the results of the treatability tests to the design of a full-scale GAC adsorption treatment facility, the following process design criteria were established:

- Maximum water flowrate and loading rate
- Empty bed contact time (EBCT)
- VOC identification
- Maximum influent and effluent concentrations
- Type of GAC carbon usage rate
- Carbon life

These design criteria then were utilized to determine the number of contactors, contactor dimensions, and carbon requirements.

Design criteria regarding the water flowrate and the influent VOC concentrations were developed previously in Chapters 2 and 3, respectively. Effluent concentrations were based on the performance of the packed column at design conditions. The number of contactors and contactor dimensions were based on a loading rate of 5 gpm/sf and an EBCT of 10 minutes. Type of GAC, carbon usage rates, and carbon life were based on the results of the mini-column adsorption tests. These design criteria are summarized in Table 23.

As indicated in Table 23, one GAC contactor would be required at the Westmoreland Wellfield, Well No. 9 and Well No. 24. The contactors would be 8 feet in diameter and about 17 feet high, and hold 8,800 pounds of GAC. Four contactors would be required to treat the combined Cadmus Place-Memorial Park wells. These contactors would be 10 feet in diameter and about 16 feet high. Each contactor will contain 12,000 pounds of GAC.

The optimum GAC is Carborundum GAC 830. Based on the results of the mini-column tests, the carbon life for the Westmoreland wells and Well No. 9 is estimated to be 56 days. For the Cadmus Place-Memorial Park wells and Well No. 24, the carbon life will be about 71 days and 5 days, respectively. These design criteria were used to determine preliminary sizes and costs of treatment facilities which are described in the following chapter.

TABLE 23

GAC ADSORPTION FACILITIES
PROCESS DESIGN CRITERIA

| Location | Hydraulic Capacity[1] | No. of Contactors | Contact. Dimen.[2] Dia.[3] | Ht. | Depth of GAC[4] | GAC per Contactor | Carbon Usage Rate[6] | Carbon Life[7] |
|---|---|---|---|---|---|---|---|---|
| Westmoreland | 225 | 1 | 8 | 17 | 7 | 8,800 | 0.55 | 56 |
| Cadmus-Memorial | 1,380 | 4 | 10 | 16 | 6 | 12,000 | 0.43 | 71 |
| Well No. 9 | 200 | 1 | 8 | 17 | 7 | 8,800 | 0.55 | 56 |
| Well Nos. 23 & 24 | 220 | 1 | 8 | 17 | 7 | 8,800 | 6.6 | 5 |

Notes:

1. Values presented in gallons per minute.
2. Values presented in feet.
3. Diameter based on surface loading rate of 5 gpm/sf.
4. Values presented in feet and based on an empty bed contact time of 10 minutes.
5. Values presented in pounds of carbon.
6. Values presented in pounds of GAC per 1,000 gallons of water treated and based on the use of Carborundum GAC 830.
7. Values presented in days.

# 8. EVALUATION OF ALTERNATIVES

As indicated in the previous chapters, the packed column aeration, diffused aeration, and GAC adsorption processes are technically capable of removing VOCs from the Borough's ground water supply. This chapter of the report presents an economic evaluation of these process alternatives to determine the optimum process for VOC removal. Also, based on the evaluation of process alternatives, descriptions and evaluations of alternative treatment strategies utilizing the optimum process are presented later in the chapter to determine the optimum number and location of treatment facilities.

The costs presented in this chapter are based on general cost models which are considered adequate for purposes of comparing alternative processes and strategies. These costs do not necessarily include site-specific conditions. More accurate and detailed cost estimates of the recommended plan are presented in the following chapter of this report.

## Process Evaluation

An evaluation of the packed column aeration, diffused aeration, and GAC adsorption processes was made to determine the most cost-effective process for controlling VOCs in the Borough's ground water supply. As indicated in the previous chapters, all three processes are capable of meeting the design criteria (no greater than 10 ug/l of any VOC in the treated water) outlined in Chapter 3 of this report. The use of GAC adsorption in conjunction with aeration is not considered necessary because only volatile organics have been found in the Borough's ground water and the aeration processes are capable of achieving the desired removals without the use of GAC adsorption. Further evaluation of the processes based on costs and operating requirements is necessary to determine the optimum process.

Description of Alternatives - The following process alternatives were considered at each of the potential sites:

Packed Column Aeration

- Westmoreland Wellfield
- Cadmus Place Wellfield
- Well No. 24
- Well No. 9

Diffused Aeration

- Westmoreland Wellfield
- Cadmus Place Wellfield

GAC Adsorption

- Westmoreland Wellfield
- Cadmus Place Wellfield
- Well No. 24
- Well No. 9

For the purpose of the process evaluation, it was assumed that each wellfield and/or well would be treated separately. The Memorial Park wells were considered to be treated at the Cadmus Place Wellfield because the Memorial Park wells currently are pumped to the Cadmus Place Wellfield. Also, Well Nos. 23 and 24 were considered to be treated together. An evaluation of alternative combinations of treatment facilities is presented in a subsequent section of this chapter.

The use of the packed column aeration process at each site would require the construction of a packed column and associated aeration and pumping equipment at each site. Also, the construction of a building to house the aeration and pumping equipment and related sitework would be required at each site. Based on the results of the packed column pilot tests presented in Chapter 5, preliminary facility requirements were determined at each site as a basis for estimating costs for this process. A summary of the estimated capital and operating costs for the packed column aeration process at the four potential sites is presented in Table 24. As indicated in the table, the cost per 1,000 gallons of water treated ranges from $0.11 at Cadmus Place to $0.34 and $0.38 at the other sites.

The use of the diffused aeration process was considered at the Westmoreland and Cadmus Place Wellfields because both of these wellfields include existing ground-level storage tanks which might be used as the diffused air basin. Storage tanks are not available at Well Nos. 24 and 9, and therefore this process was not evaluated to treat the flow from these wells. Implementation of the diffused aeration process at the Westmoreland and Cadmus Place Wellfields would require modifications (such as air vents, access doors, piping inlets and an internal baffle) to the storage tanks at each site to accommodate the necessary aeration equipment. Also, the construction of a building to house the aeration equipment would be required. Preliminary capital and operating costs for the diffused aeration process at Westmoreland and Cadmus are presented in Table 25. The costs for diffused aeration are $0.60 per 1,000 gallons of water treated at Cadmus and $1.31 per 1,000 gallons of water treated at Westmoreland.

The use of GAC adsorption at each site would involve the installation of one carbon contactor at the Westmoreland Wellfield, Well No. 9, and Well No. 24 and four contactors at Cadmus Place to provide sufficient contact time for VOC removal. Also, it would be necessary to construct a building to house the contactors to prevent freezing problems during the winter months. Preliminary cost estimates for the construction and operation of GAC adsorption systems at each of the potential sites are presented in Table 26. These costs range from $0.58 per 1,000 gallons of water treated at Cadmus to $7.06 per 1,000 gallons of water treated at Well No. 24.

TABLE 24

PRELIMINARY COST ESTIMATES FOR
PACKED COLUMN AERATION PROCESS

| Capital Costs | Westmoreland | Cadmus Place | Well No. 9 | Well Nos. 23 & 24 |
|---|---|---|---|---|
| Packed Column/Clearwell[1] | $ 80,000 | $150,000 | $ 80,000 | $ 80,000 |
| Aeration Equipment[2] | 8,000 | 13,000 | 8,000 | 8,000 |
| Repumping[3] | 25,000 | 50,000 | 25,000 | 25,000 |
| Housing/Sitework | 35,000 | 40,000 | 35,000 | 35,000 |
| Total Construction Cost | $148,000 | $253,000 | $148,000 | $148,000 |
| Contingencies and Engineering (30 percent) | 45,000 | 76,000 | 45,000 | 45,000 |
| Total Capital Cost | $193,000 | $329,000 | $193,000 | $193,000 |
| Equivalent Annual Cost[4] | $ 24,000 | $ 41,000 | $ 24,000 | $ 24,000 |
| **Operating Costs** | | | | |
| Power[5] | $ 12,000 | $ 33,000 | $ 12,000 | $ 12,000 |
| Labor | 1,000 | 2,000 | 1,000 | 1,000 |
| Maintenance Materials | 3,000 | 4,000 | 3,000 | 3,000 |
| Total Operating Cost | $ 16,000 | $ 39,000 | $ 16,000 | $ 16,000 |
| Total Equivalent Annual Cost | $ 40,000 | $ 80,000 | $ 40,000 | $ 40,000 |
| $/1,000 Gallons | $ 0.34 | $ 0.11 | $ 0.38 | $ 0.34 |

Notes:

1. Includes: Shell, packing and clearwell.
2. Includes: Blower, accessories, and piping.
3. Includes: Pumps and interior pumping.
4. Based on amortization of the capital cost over a 20-year period at an 11 percent interest rate.
5. Includes: Blowers, booster pumps and lighting power.

TABLE 25

PRELIMINARY COST ESTIMATES FOR DIFFUSED AERATION PROCESS

| Capital Costs | Westmoreland | Cadmus Place |
|---|---|---|
| Modifications to Storage Tank(1) | $ 75,000 | $ 75,000 |
| Aeration Equipment(2) | 100,000 | 500,000 |
| Housing/Sitework | 18,000 | 25,000 |
| Total Construction Cost | $193,000 | $600,000 |
| Contingencies and Engineering (30 percent) | 58,000 | 180,000 |
| Total Capital Cost | $251,000 | $780,000 |
| Equivalent Annual Cost(3) | $ 32,000 | $ 98,000 |
| **Operating Costs** | | |
| Power(4) | $ 73,000 | $296,000 |
| Labor(5) | 15,000 | 20,000 |
| Maintenance Materials | 5,000 | 12,000 |
| Total Operating Cost | $123,000 | $328,000 |
| Total Equivalent Annual Cost | $155,000 | $426,000 |
| $/1,000 Gallons | $ 1.31 | $ 0.60 |

Notes:

1. Includes: Air vents, access doors, piping inlets, and internal baffle.
2. Includes: Blowers, static aerators, piping, electrical equipment and instrumentation.
3. Based on amortization of the capital cost over a 20-year period at an 11 percent interest rate.
4. Includes: Blowers, lighting and heating power.
5. Includes: Inspection and maintenance time.

TABLE 26

PRELIMINARY COST ESTIMATES FOR GAC ADSORPTION PROCESS

| Capital Costs | Westmoreland | Cadmus Place | Well No. 9 | Well Nos. 23 & 24 |
|---|---|---|---|---|
| GAC Contactors | $160,000 | $300,000 | $160,000 | $160,000 |
| GAC | 9,000 | 48,000 | 9,000 | 9,000 |
| Housing/Sitework | 50,000 | 100,000 | 50,000 | 50,000 |
| Total Construction Cost | $219,000 | $448,000 | $219,000 | $219,000 |
| Contingencies and Engineering (30 percent) | 66,000 | 134,000 | 66,000 | 66,000 |
| Total Capital Cost | $285,000 | $582,000 | $285,000 | $285,000 |
| Equivalent Annual Cost (1) | $ 36,000 | $ 73,000 | $ 36,000 | $ 36,000 |
| **Operating Costs** | | | | |
| Power | $ 3,000 | $ 9,000 | $ 3,000 | $ 3,000 |
| Labor | 7,000 | 11,000 | 6,000 | 7,000 |
| Maintenance Materials | 7,000 | 11,000 | 6,000 | 7,000 |
| Carbon Replacement | 65,000 | 305,000 | 58,000 | 763,000 |
| Total Operating Cost | $ 82,000 | $336,000 | $ 73,000 | $780,000 |
| Total Equivalent Annual Cost | $118,000 | $409,000 | $109,000 | $816,000 |
| $/1,000 Gallons | $ 1.00 | $ 0.58 | $ 1.04 | $ 7.06 |

Note:

1. Based on amortization of the capital cost over a 20-year period at an 11 percent interest rate.

Comparison of Processes - A comparison of the costs for each process at each potential treatment site is presented in Table 27. As indicated in the table, the packed column aeration process represents the lowest cost alternative at each site.

At the Westmoreland Wellfield, the packed column aeration process is about one-third the cost of diffused aeration or GAC adsorption. Although the capital costs for each process generally are similar, the operating costs for the packed column aeration process are much less than those for the other two processes. The high operating cost associated with the diffused aeration system results from the use of high-horsepower compressors to supply air for the process, while the high operating cost of the GAC process results from the need to replace the GAC about six times per year.

At the Cadmus Place Wellfield, the packed column aeration process also is about one-third the cost of the other two processes. The capital cost for the packed column process is almost one-half the cost of the other processes, while the operating cost is less than one-quarter that for the other processes.

At Well No. 24, the high VOC concentrations in the water would result in very frequent (about once every week) replacement of the GAC. Consequently, the total equivalent annual cost of the GAC adsorption process is almost 20 times that of the packed column aeration process. At Well No. 9, the packed column aeration process is about one-third the cost of the GAC adsorption process.

In addition to the difference in costs, operating requirements for each process vary considerably. Operation of the two aeration processes probably would be similar, in that the equipment would be operated continuously unless there is a breakdown with the aeration equipment. Maintenance of the diffused aeration equipment probably would be more

TABLE 27

COMPARISON OF PROCESS ALTERNATIVES
(Costs in $1,000's)

| | Packed Column | Diffused Air | GAC Adsorption |
|---|---|---|---|
| **Westmoreland Wellfield** | | | |
| Total Capital Cost | $ 193 | $ 251 | $ 285 |
| Total Operating Cost | 16 | 123 | 82 |
| Total Equivalent Annual Cost | $ 40 | $ 155 | $ 118 |
| $/1,000 Gallons | $0.34 | $1.31 | $1.00 |
| **Cadmus Place Wellfield** | | | |
| Total Capital Cost | $ 329 | $ 780 | $ 582 |
| Total Operating Cost | 39 | 328 | 336 |
| Total Equivalent Annual Cost | $ 80 | $ 426 | $ 409 |
| $/1,000 Gallons | $0.11 | $0.60 | $0.58 |
| **Well No. 24** | | | |
| Total Capital Cost | $ 193 | - | $ 285 |
| Total Operating Cost | 16 | - | 780 |
| Total Equivalent Annual Cost | $ 40 | - | $ 816 |
| $/1,000 Gallons | $0.34 | - | $7.06 |
| **Well No. 9** | | | |
| Total Capital Cost | $ 193 | - | $ 285 |
| Total Operating Cost | 16 | - | 73 |
| Total Equivalent Annual Cost | $ 40 | - | $ 109 |
| $/1,000 Gallons | $0.38 | - | $1.04 |

extensive than that of the packed column aeration equipment because of the larger equipment required with diffused aeration. In contrast, operation of the GAC adsorption process would involve a scheduled downtime because of the frequent replacement necessary for the GAC. Replacement of the GAC also would involve the handling and disposal of backwash which is generated when the GAC is placed in the contactors. With the use of the packed column aeration process, the treatment system may be kept in service during maintenance, or even repair, of the blower because some removals will be achieved even without an induced draft.

Optimum Process - Based on the economic and operational comparison of alternatives discussed above, the packed column aeration process represents the most cost-effective process for controlling VOCs in the Borough's ground water supply. This process will achieve the necessary high VOC removals at a much lower cost than the other treatment processes. Also, in view of the high influent VOC concentrations, the packed column process would be easier to operate and maintain than the GAC adsorption process. An evaluation of alternative treatment facility locations and sizes using the packed column aeration process is presented in the following section of this chapter.

## Strategy Evaluation

The previous section of this chapter indicate that packed column aeration is the most technically and economically feasible treatment process for removing VOCs from the Borough's ground water supply. This section presents descriptions and evaluations of alternative treatment strategies utilizing the packed column process. Cost estimates are made for each alternative including initial construction costs and operating costs. A comparison of the alternative strategies is then made on the basis of the cost estimates and noneconomic factors to determine the optimum number and location of treatment facilities.

Description of Alternatives - The following treatment strategies were considered for controlling VOCs in the Borough's ground water supply:

- Strategy No. 1 --One Treatment Facility: Centralized treatment of all wells with one packed column located at the Cadmus Place Wellfield.

- Strategy No. 2 --Three Treatment Facilities: Individual treatment facilities for the combined Cadmus Place-Memorial Park wells at Cadmus Place and Well No. 9 at George Street. Well Nos. 10, 11, 14, 23 and 24 would be treated at a central facility at the Westmoreland Wellfield.

- Strategy No. 3 -- Three Treatment Facilities: Individual treatment facilities for the combined Westmoreland wells and Well No. 9. The Cadmus Place-Memorial Park wells and Well Nos. 23 and 24 would be treated at a central facility at the Cadmus Place Wellfield.

- Strategy No. 4 -- Three Treatment Facilities: Individual treatment facilities for the combined Westmoreland wells and the combined flow from Well Nos. 23 and 24. The Cadmus Place-Memorial Park wells and Well No. 9 would be treated at a central facility at the Cadmus Place Wellfield.

- Strategy No. 5 -- Four Treatment Facilities: Individual treatment facilities for: 1) the Cadmus Place-Memorial Park wells at Cadmus Place, 2) the Westmoreland Wellfield, 3) Well No. 9, and 4) the combined flow from Well No. 23 and 24 at Pollitt Drive.

- Strategy No. 6 -- Two Treatment Facilities: The first would be located at Cadmus Place and treat water from the Cadmus Place-Memorial Park Wellfields and Well No. 9. The second facility would be located at the Westmoreland Wellfield and treat water from Well Nos. 10, 11, 14, 23 and 24.

With the exception of Strategy No. 5, the alternatives will require the construction of interconnecting pipelines to convey water from affected wells to a centralized treatment site. Strategy No. 5 involves the use of individual treatment systems and does not require the construction of any water mains.

Strategy No. 1 will require three water mains:

1. From Well No. 9 to the 12-inch diameter low pressure main conveying water from the Memorial Park wells to Cadmus Place.

2. From Well Nos. 23 and 24 to Cadmus Place.

3. From the Westmoreland Wellfield to Cadmus Place.

In addition, the pump motors for Well Nos. 10, 11 and 14 may have to be modified so that water can be pumped to Cadmus Place. Treatment Strategy No. 2 will require a water main to convey water from Well Nos. 23 and 24 to the Westmoreland Wellfield. A 6-inch diameter main from Well Nos. 23 and 24 would follow Pollitt Drive to McBride Avenue. At the end of McBride Avenue, the pipe would be jacked under New Jersey Route No. 208 and then follow the route of an existing 16-inch diameter main to the Westmoreland Wellfield. Strategy No. 3 would involve the construction of a 6-inch diameter main from Well Nos. 23 and 24 to Cadmus Place. Strategy No. 4 would require the construction of a main from Well No. 9 to the 12-inch diameter low pressure line which conveys water from the Memorial Park wells to Cadmus Place. The proposed main from Well No. 9 would follow River Road and intercept the low pressure main at Bellair Avenue. Strategy No. 6 would require the construction of two water mains:

1. From Well Nos. 23 and 24 to the Westmoreland Wellfield similar to that for Strategy No. 2.

2. From Well No. 9 to the 12-inch diameter low pressure main at the intersection of River Road and Bellair Avenue similar to that for Strategy No. 4.

The cost estimates for each of the alternative treatment strategies include the cost of the required water main construction.

The size of the packed column facilities required for each treatment strategy were based on design criteria developed in Chapter 5. The design criteria for the treatment strategies, including hydraulic capacity, packing height, A:W ratio and air flowrate are presented in Table 28.

Comparison of Strategies - The comparison of the alternative treatment strategies was based on economic and noneconomic factors. Cost estimates were developed for each strategy on the basis of the design criteria presented in Table 28. A comparison of the estimated capital and operating costs for packed column aeration facilities and water mains for each strategy are presented in Table 29.

The capital costs of the alternative strategies are somewhat similar and range from $849,000 to $1,009,000. The alternatives involving one or more centralized treatment facilities have lower packed column equipment costs. These savings, however, are offset by the cost of water main construction required to transport water from affected wells to the centralized treatment facility. As a result, there is no significant capital cost advantage in utilizing centralized treatment.

Operating costs, however, are lower for those alternatives (Strategy No. 1 and Strategy No. 6) involving the fewest treatment facilities. As shown in Table 29, Strategy Nos. 2, 3, 4 and 5, which involve three or four treatment facilities, have higher annual operating costs than Strategy Nos. 1 and 6, which involve one and two treatment facilities, respectively.

The total cost per 1,000 gallons of water treated for each alternative is similar and ranges from $0.16 to $0.18. Because total costs are similar, the alternatives with the lowest operating costs will result in the lowest overall cost over the life of the facility because of the effects of inflation. Therefore, based on the lowest annual operating

TABLE 28

ALTERNATIVE TREATMENT STRATEGIES
PROCESS DESIGN CRITERIA FOR
PACKED COLUMN AERATION FACILITIES

| Facilities | Hydraulic Capacity (gpm) | Column[1] Diameter (ft) | Packing Height (ft) | A:W Ratio | Air Flow (cfm) |
|---|---|---|---|---|---|
| **Strategy No. 1** | | | | | |
| Cadmus Place | 1,995 | 10 | 18 | 45:1 | 12,000 |
| **Strategy No. 2** | | | | | |
| Cadmus Place | 1,350 | 9 | 15 | 35:1 | 6,500 |
| Westmoreland | 445 | 5 | 21 | 45:1 | 3,000 |
| Well No. 9 | 200 | 4 | 20 | 45:1 | 1,200 |
| **Strategy No. 3** | | | | | |
| Cadmus Place | 1,570 | 9 | 17 | 45:1 | 9,500 |
| Westmoreland | 225 | 4 | 20 | 40:1 | 1,200 |
| Well No. 9 | 200 | 4 | 20 | 45:1 | 1,200 |
| **Strategy No. 4** | | | | | |
| Cadmus Place | 1,550 | 9 | 16 | 40:1 | 8,500 |
| Westmoreland | 225 | 4 | 20 | 40:1 | 1,200 |
| Well Nos. 23 & 24 | 220 | 4 | 21 | 50:1 | 1,500 |
| **Strategy No. 5** | | | | | |
| Cadmus Place | 1,350 | 9 | 15 | 35:1 | 6,500 |
| Westmoreland | 225 | 4 | 20 | 40:1 | 1,200 |
| Well No. 9 | 200 | 4 | 20 | 45:1 | 1,200 |
| Well Nos. 23 & 24 | 220 | 4 | 24 | 50:1 | 1,500 |
| **Strategy No. 6** | | | | | |
| Cadmus Place | 1,550 | 9 | 16 | 40:1 | 8,500 |
| Westmoreland | 445 | 5 | 21 | 45:1 | 3,000 |

Note:

1. Based on a liquid loading rate of 25 gpm/sf.

TABLE 29

ALTERNATIVE TREATMENT STRATEGIES
PRELIMINARY COST ESTIMATES FOR
PACKED COLUMN AERATION FACILITIES
(Costs in $1,000's)

| | Treatment Strategy No.[1] | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| **Capital Costs** | | | | | | |
| Packed Column/Clearwell | $265 | $332 | $ 383 | $375 | $390 | $337 |
| Aeration Equipment | 16 | 27 | 28 | 29 | 37 | 23 |
| Repumping | 57 | 97 | 91 | 90 | 125 | 79 |
| Housing/Sitework | 60 | 100 | 110 | 110 | 145 | 80 |
| Pipe Jacking | - | 75 | - | - | - | 75 |
| Water Mains | 302 | 91 | 164 | 49 | - | 140 |
| Total Construction Cost | $700 | $722 | $ 776 | $653 | $697 | $734 |
| Contingencies and Engineering (30%) | 210 | 217 | 233 | 196 | 209 | 220 |
| Total Capital Cost | $910 | $939 | $1,009 | $849 | $906 | $954 |
| Equivalent Annual Cost | $114 | $118 | $ 127 | $107 | $114 | $120 |
| **Operating Costs** | | | | | | |
| Power | $ 46 | $ 47 | $ 50 | $ 50 | $ 54 | $ 41 |
| Labor | 3 | 5 | 5 | 5 | 5 | 4 |
| Maintenance Materials | 7 | 9 | 10 | 10 | 13 | 9 |
| Total Operating Cost | $ 56 | $ 61 | $ 65 | $ 65 | $ 72 | $ 54 |
| Total Equivalent Annual Cost | $170 | $179 | $ 192 | $172 | $186 | $174 |
| $/~~1,000~~ gallons MILLION ? | $ 0.16 | $0.17 | $ 0.18 | $0.16 | $0.18 | $0.17 |

Note:

1. Strategy No. 1: One Treatment Facility
   Strategy No. 2: Three Treatment Facilities
   Strategy No. 3: Three Treatment Facilities
   Strategy No. 4: Three Treatment Facilities
   Strategy No. 5: Four Treatment Facilities
   Strategy No. 6: Two Treatment Facilities

costs, Treatment Strategy Nos. 1 and 6 represent the most cost-effective alternatives.

Noneconomic Factors - In addition to the above economic factors, two noneconomic factors must be considered in determining the optimum alternative. The noneconomic factors include:

- Water distribution
- Staging of construction

The location of the treatment facility may have an effect on the operation of the Borough's distribution system. If Strategy No. 1 is utilized, all of the Borough's ground water supply would be distributed from the Cadmus Place Booster Pump Station. This may create pressure problems in some parts of the distribution system, particularly in those areas which now receive water from the Westmoreland wells. As a result, it may be necessary to pump treated water from Cadmus Place back to the Westmoreland ground-level storage tank and then repump into the distribution system using the Westmoreland Booster Station.

The determination of the effects of distributing all treated water from Cadmus Place would require an hydraulic analysis of the distribution system which is beyond the scope of this report. However, if it were necessary to pump treated water to the Westmoreland ground-level storage tank, the capital and operating costs of Strategy No. 1 would increase significantly.

The use of Strategy No. 6, however, would not create any problems in the distribution of water. Well No. 9 would be treated at and distributed from Cadmus Place. Well Nos. 23 and 24 would be treated at and distributed from the Westmoreland Wellfield. As a result, the affected wells will be treated in the general area in which they are located and the use of Strategy No. 6 should not create any distribution problems.

Staging of construction relates to the sequence in which the treatment facilities would be built. For Strategy No. 1, a single packed column would be built at Cadmus Place to treat water from all of the Borough's affected wells. If Strategy No. 6 is implemented, treatment facilities can be provided where and when they are required. Utilization of Strategy No. 6 would provide more flexibility in the construction of treatment facilities.

Optimum Strategy - Based on the results of the cost comparison, Strategy Nos. 1 and 6 are the most cost-effective alternatives on the basis of annual operating costs. Capital and operating costs for Strategy Nos. 1 and 6 were about the same. However, consideration of two noneconomic factors, water distribution and staging of construction, indicate that Strategy No. 6 is the optimum alternative. The use of Strategy No. 6 will not cause any problems in the distribution system and will permit for staging of construction. Therefore, based on the consideration of economic and noneconomic factors, Strategy No. 6 represents the optimum alternative for controlling VOCs in the Borough's ground water supply. Detailed descriptions, layouts and cost estimates of the recommended treatment facilities at the Westmoreland and Cadmus-Memorial Wellfields are presented in the following chapter.

## Comparison of Treated Water Versus Purchased Water

As indicated in Table 29, the estimated cost of treating the water from the Borough's wells to remove VOCs is $0.17 per 1,000 gallons of water treated, or $170 per million gallons of water treated. Currently, the cost of pumping water from the wells and into the distribution system is estimated to be $280 per million gallons, including chlorination of the water. In the future, if the wells are rehabilitated to restore pumping capacity, the cost of pumping water will be reduced to about $210 per million gallons. Therefore, the total cost of providing water to Borough residents would be $450 per million gallons if VOC treatment facilities are installed, based on current water costs, and $380 per million gallons based on possible future water costs. — IF WELLS REHABED? ?

The current cost of purchasing water from the Passaic Valley Water Commission (PVWC) is $515 per million gallons of water purchased, which is about 13 percent higher than the estimated cost of treated Borough water based on current water costs, and 26 percent higher based on potential future water costs. On this basis, treatment of the Borough's wells to remove VOCs would be less expensive than purchasing water from PVWC. + HACKENSACK WATER?

WHAT ABOUT NEW WELLS?

# 9. CONCLUSIONS AND RECOMMENDATIONS

The Borough of Fair Lawn owns and operates a ground water supply system with a capacity to provide approximately 50 percent of the Borough's current potable water demand. Historically, the Borough's ground water supply has exhibited very good quality, requiring only disinfection prior to pumping into the distribution system. However, in 1979, volatile organic chemicals (VOCs) were detected in several of the Borough's wells. The levels of VOCs in the Westmoreland wells and in Well No. 24 have been higher than the current guidelines used by the New Jersey Department of Environmental Protection (NJDEP), resulting in the Borough's decision to take these wells out of service. Currently, the Borough's well supply has been reduced to about 80 percent of its normal capacity because of the effects of VOCs.

A previous hydrogeological study conducted for the Borough evaluated the movement of VOCs in the ground water and identified alternatives for containment and recovery of the affected ground water. The optimum solution was determined to be treatment of the affected wells, thereby restricting the widespread movement of the VOCs and purging the aquifer.

NOT SO! WELL RELOCATION NOT ADEQUATELY EVALUATED!

The previous chapters of this report present an evaluation of treatment processes and strategies available to the Borough for controlling VOCs in the ground water supply. Based on the findings and conclusions presented in the previous chapters, final recommendations concerning the most feasible treatment process and strategy for treating the Borough's wells to meet current NJDEP guidelines and probable future federal regulations for VOCs in drinking water are outlined in this chapter. Also, preliminary layouts, cost estimates, and project schedules for the recommended treatment facilities are included in this chapter.

Recommended Treatment Process

As indicated previously in Chapter 4 of this report, several treatment processes are available for reducing the levels of VOCs in drinking water. These include diffused aeration, packed column aeration, and granular activated carbon (GAC) adsorption. Treatability tests of each of these processes were conducted as part of this study to determine removal efficiencies and design criteria for full-scale treatment facilities. The result of the treatability tests, which are summarized in Chapters 5, 6 and 7, indicate that each of these processes is capable of achieving high removals of VOCs from the Borough's wells.

Further evaluation of each of these processes was conducted to determine preliminary capital and operating costs of each alternative. An economic comparison of the three alternative processes, which is presented in Chapter 8, indicates that the packed column aeration process is the most economically feasible alternative for removing the VOCs detected in the Borough's wells.

The packed column aeration process involves the transfer of the VOCs from the water to the air by causing the water to flow over packing material, thus breaking the water into small droplets or thin films. Air is forced up through the packing material to provide additional water turbulence and to accept the VOCs which are removed from the water. This design results in continuous and thorough contact of the water with the air and minimizes the thickness of the water layer on the packing, thus promoting efficient transfer of the VOCs from the water to the air.

The results of the treatability tests indicate that this process is capable of achieving the high removal efficiencies which are required to reduce the VOCs in the Borough's wells to below current NJDEP guidelines and potential future regulations. The recommended aeration process will be designed to provide flexibility in the event VOC levels should rise above the design influent levels which are developed in Chapter 3 or future regulations require lower levels than those which are being used for design purposes. Higher removal efficiencies may be achieved by increasing the air:water ratio with the use of larger blowers.

Based on operating results of full-scale packed columns in the northeastern United States, the use of the packed column process will not be plagued by freezing problems during winter operations. Also, because of the relatively low concentrations (no greater than 1 to 2 milligrams per liter) of VOCs in the Borough's water and the large volumes of air used in the process, the concentration of VOCs in the air immediately surrounding the column and the emission rate will be less than regulatory limits for these compounds. Based on current pumping rates and average influent VOC concentrations, the estimated VOC concentration in the air surrounding the column and the hourly VOC discharge for the VOCs subject to NJDEP regulations are presented below:

| | VOC Concentration in Air (ppm) | Emission Rate (lb/hour) |
|---|---|---|
| Cadmus Place Treatment Facility | | |
| Carbon Tetrachloride | 0.02 | 0.005 |
| Trichloroethylene | 0.05 | 0.012 |
| Tetrachloroethylene | 0.08 | 0.002 |
| Chloroform | 0.03 | 0.004 |
| Total | 0.18 | 0.023 |
| Westmoreland Treatment Facility | | |
| Carbon Tetrachloride | 0.3 | 0.01 |
| Trichloroethylene | 0.9 | 0.03 |
| Tetrachloroethylene | 0.6 | 0.02 |
| Chloroform | 0.6 | 0.02 |
| Total | 2.4 | 0.08 |

Dispersion and chemical breakdown of the VOCs in the atmosphere will help to further reduce concentrations in the air away from the column.

Recommended Treatment Strategy

An evaluation of the location and sizing of treatment facilities, using the packed column aeration process, is discussed in the previous chapter of this report. Based on an economic and qualitative comparison of several treatment strategies, the most cost-effective strategy involves the construction of two treatment facilities -- one at the Cadmus Place Wellfield and one at the Westmoreland Wellfield -- to serve the following wells:

Cadmus Place Treatment Facility

- Cadmus Place Well Nos. 2, 3, 4, 5, 6 and 7
- Memorial Park Well Nos. 15, 16, 17 and 19
- Well No. 9

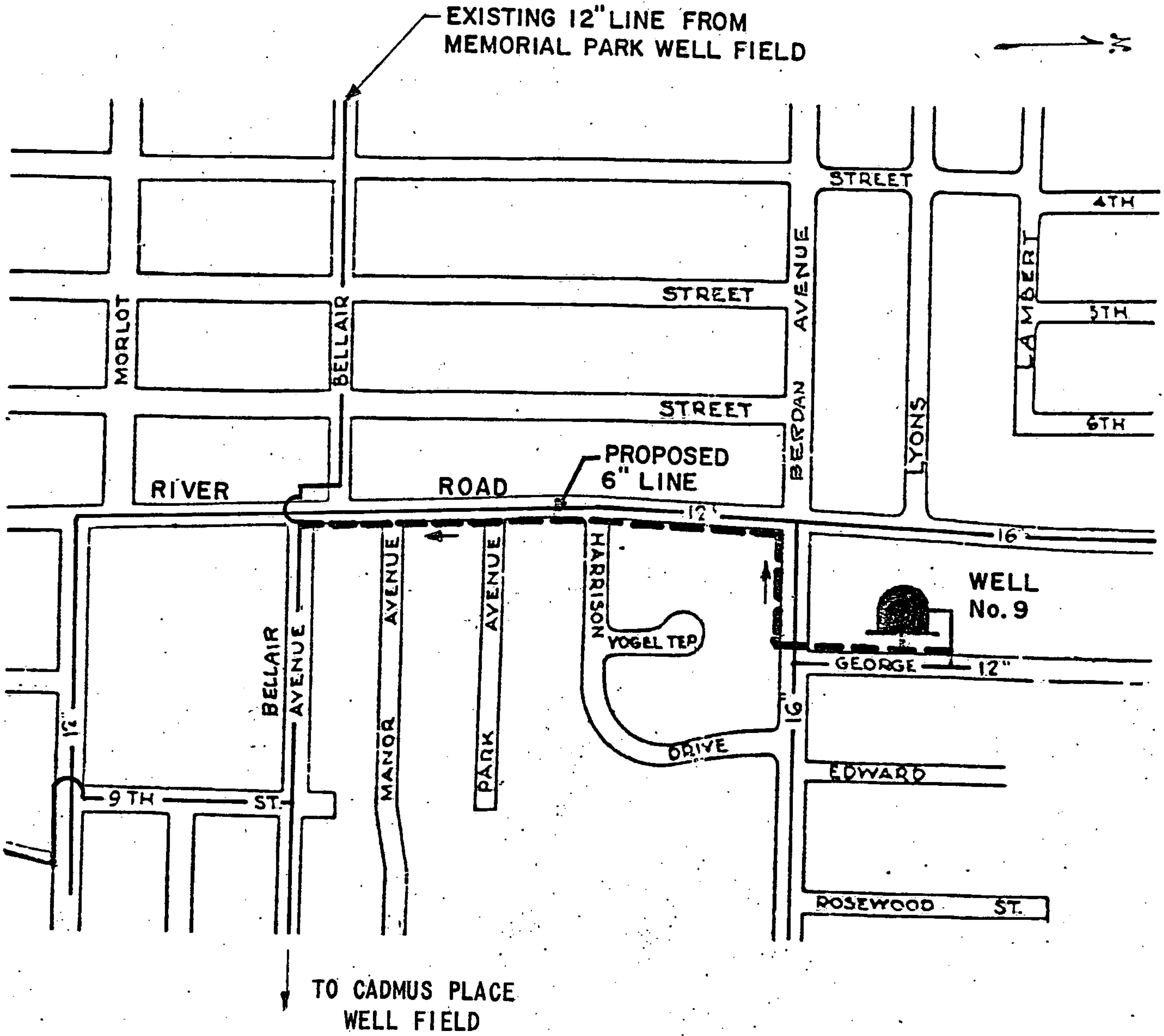
Westmoreland Treatment Facility

- Westmoreland Well Nos. 10, 11 and 14
- Well Nos. 23 and 24

As indicated above, Well No. 9 would be pumped to the Cadmus Place Wellfield for treatment, and Well Nos. 23 and 24 would be pumped to the Westmoreland Wellfield for treatment.

Several routes were evaluated for conveying the water from Well Nos. 9, 23 and 24 to their respective treatment facilities. The route which provides the lowest cost and the lowest total headloss to convey the flow from Well No. 9 to the proposed Cadmus Place Treatment Facility is shown on Figure 28. A proposed 6-inch line would be installed along George Street to Berdan Avenue, then proceed to River Road and along River Road to Bellair Avenue. The proposed line would tie into an existing 12-inch line which conveys flow from the Memorial Park Wellfield to the Cadmus Place Wellfield. About 2,000 linear feet of 6-inch line would be required to make this connection.

The route which results in the lowest cost and lowest total headloss to convey flows from Well Nos. 23 and 24 to the proposed Westmoreland Treatment Facility is shown on




SCALE: 1" = 350'

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

PROPOSED INTERCONNECTION
FOR WELL NO. 9

Figure 29. A proposed 6-inch line would be installed along Pollitt Drive to McBride Avenue, then proceed to New Jersey Route 208. At this point, the pipeline would be "jacked" under Route 208 using a 24-inch pipeline to carry the proposed 6-inch line. From Route 208, the pipeine would proceed along Henderson Brook, cross 11th Street, and proceed to the treatment facility. About 4,000 feet of 6-inch line is required to make this connection. The proposed treatment facilities at each location are described in the following paragraphs.

Westmoreland Treatment Facility - The packed column aeration treatment facility at the Westmoreland Wellfield would be located adjacent to the existing ground storage tank, as shown on Plate 1 which is included at the end of this report. A connection would be made to the existing 8-inch line which conveys flows from Well Nos. 10, 11 and 14 to the ground storage tank. Flows would be routed to the treatment facility, and tie back into the 8-inch line prior to proceeding to the existing chlorinator. The existing chlorinator may have to be expanded to provide additional capacity for chlorination of the flow from Well Nos. 23 and 24, in addition to the Westmoreland wells.

COST INCLUDED?

A preliminary layout and schematic diagram of the proposed packed column aeration system is shown on Plate 1. The layout of equipment shown on Plate 1 is preliminary, and may be revised during final design to develop an optimum floor plan. The design criteria of the system are summarized in Table 30.

The proposed aeration system would consist of a packed column, blower, a reinforced-concrete clearwell, vertical turbine booster pumps, an insulated, butler-type building (approximately 13 feet by 15 feet) to house the blower and the booster pumps, and ancillary equipment such as piping, valves and controls. The column would be constructed of

NOISE LEVEL?
PROXIMITY OF RESIDENTS?

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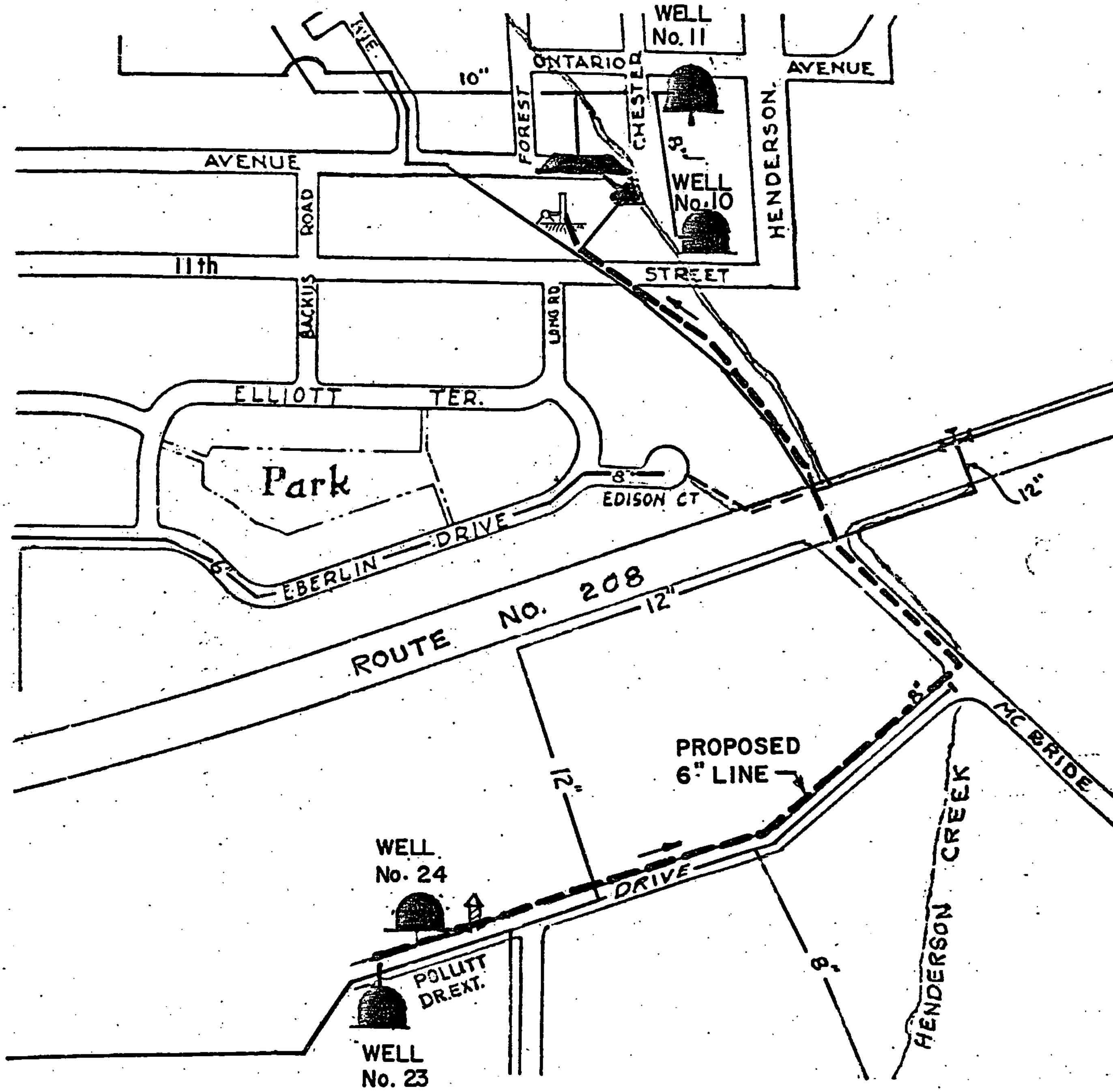


SCALE: 1" = 350'

MALCOLM PIRNIE

BOROUGH OF FAIR LAWN, NEW JERSEY
ORGANIC CHEMICAL TREATMENT FACILITIES
AT AFFECTED BOROUGH WELLS

PROPOSED INTERCONNECTION
FOR WELL NOS. 23 AND 24

TABLE 30

DESIGN CRITERIA FOR
WESTMORELAND TREATMENT FACILITY

| | |
|---|---|
| Wells Treated: | Nos. 10, 11, 14, 23 and 24 |
| Maximum Flowrate: | 445 gpm = .64 MGD |
| Hydraulic Loading Rate: | 25 gpm/sf |
| No. of Columns: | 1 |
| Column Diameter: | 5 feet |
| Packing Height: | 21 feet |
| Column Height: | 27 feet |
| Air Flowrate: | 2,700 cfm |
| Air:Water Ratio: | 50:1 cf:cf |
| No. of Blowers: | 1 |
| Clearwell: | |
| Detention Time: | 10 minutes |
| Capacity: | 4450 gallons |
| Intermediate Booster Pumps: | |
| No.: | 3 (one as standby) |
| Capacity: | 225 gpm (each) |

aluminum to prevent corrosion problems and thus minimize maintenance. A ladder would be provided to gain access to the top of the column, with manways located along the column for inspection of the interior. The packed column would not be housed because it has been demonstrated at other packed column installations that winter conditions do not affect the operation or efficiency of the column. ?

As shown in the schematic diagram on Plate 1, water from the wells would be pumped up to the top of the packed column and distributed over the packing material, which would be similar to that used in the pilot tests (2-inch Tri-packs, as manufactued by Jaeger Tri-Packs, Inc. of Fountain Valley, California). Air would be blown up through the column to provide a countercurrent flow of water and air. A centrifugal blower (10 hp) would be used to supply air for the system. An intake filter would be provided on the blower to remove any particulate matter from the air. The use of one blower is proposed because, even if the blower were down for repairs, the column may be operated and will achieve some VOC removal.

OR EQUAL !

Treated water would be collected in the clearwell located under the blower and pump building. Three vertical turbine booster pumps (each 5 hp) would be provided to pump the treated water from the clearwell into the ground water tank. Each pump would be sized to handle one-half the flow from the treatment facility. Consequently, two pumps would be operating at all times, with one pump acting as a standby. The existing booster pumping capacity at the Westmoreland Wellfield is considered sufficient to handle the combined flows from the Westmoreland wells and from Well Nos. 23 and 24.

The existing well pumps at Well Nos. 10, 11 and 14 will be operating at about the same total head as under current operating conditions. However, the well pumps at Well

Nos. 23 and 24 will be operating at a much lower total head than under current operating conditions. The existing well pumps at Well Nos. 23 and 24 could be restaged to reduce the head on the pumps because less head is required to pump water from the wells to the top of the column than currently required to pump water into the distribution system. However, the cost of restaging the existing well pumps is high compared to the savings in power costs which would be realized because the current pump motors are relatively small (15 horsepower). The payback period for restaging the pumps is estimated to be 10 to 20 years. Therefore, for purposes of this analysis, the existing well pumps were not considerd to be modified to reduce the head on the pumps. However, if during normal maintenance, a pump must be repaired or replaced, it should be sized according to its new use. Restaging a well pump during normal repair or replacement would be cost effective.

In the past, the flow from Well No. 10 has included sand and silt from the well. These materials may affect the operation of the packed column, and therefore it may be necessary to install a desander at Well No. 10. The need for a desander at this well will be determined during final design. COST INCLUDED?

The treatment system will be designed to provide an overall removal efficiency of 98 percent. The total VOC concentration in the column effluent is estimated to be less than or equal to 34 ug/l, which is well below the current NJDEP guideline of 100 ug/l.

Cadmus Place Treatment Facility - The packed column aeration treatment facility at the Cadmus Place Wellfield would be located adjacent to the existing ground storage tank, as shown on Plate 2 which is included at the end of this report. As shown on the plate, connections would be made to the existing 12-inch line which convey flows from the Cadmus Place and Memorial Park wells to the ground storage tank. Flows would be routed to the treatment facility, and tie back into the 12-inch line prior to entering the existing storage tank. The existing chlorinator at the Cadmus Place booster pumping station appears to be adequate to provide chlorination of the flow from the Cadmus Place and Memorial Park wells, in addition to Well No. 9.

A preliminary layout and schematic diagram of the proposed packed column aeration system is shown on Plate 2. The layout of equipment shown on Plate 2 is preliminary, and may be revised during final design to develop an optimum floor plan. The design criteria of the system are summarized in Table 31.

The aeration system at the Cadmus Place Wellfield would be similar to that described previously for the Westmoreland Treatment Facility. As shown on Plate 2, water from the wells would be pumped up to the top of the packed column and distributed over the packing material. Treated water would be collected in the clearwell located under the blower and pump building. Three vertical turbine booster pumps would be provided to pump the treated water from the clearwell into the ground storage tank. The existing booster pumping capacity at the Cadmus Place Wellfield is considered sufficient to handle the additional flow from Well No. 9.

The existing well pumps at the Cadmus Place and Memorial Park wells will be operating at about the same total head as under current operating conditions. However, the well pump at Well No. 9 will be operating at a much lower total head than under current operating conditions. The existing well pump could be restaged to reduce the head on the pump because less head is required to pump water from the well to the top of the column than currently required to pump water into the distribution system. However, the cost of restaging the existing well pump is high compared to the savings in power costs which would be realized because the current pump motor

TABLE 31

DESIGN CRITERIA FOR
CADMUS PLACE TREATMENT FACILITY

| | |
|---|---|
| Wells Treated: | Nos. 2, 3, 4, 5, 6, 7, 9, 15 16, 17 and 19 |
| Maximum Flowrate: | 1,580 gpm |
| Hydraulic Loading Rate: | 25 gpm/sf |
| No. of Columns: | 1 |
| Column Diameter: | 9 feet |
| Packing Height: | 16 feet |
| Column Height: | 22 feet |
| Air Flowrate: | 8,300 cfm |
| Air:Water Ratio: | 40:1 cf:cf |
| No. of Blowers: | 1 |
| Clearwell: | |
| Detention Time: | 10 minutes |
| Capacity: | 16,000 gal |
| Intermediate Booster Pumps: | |
| No.: | 3 (one as standby) |
| Capacity: | 790 gpm (each) |

is relatively small (15 horsepower). The payback period for restaging the pumps is estimated to be 10 to 20 years. Therefore, for purposes of this analysis, the existing well pump was not considered to be modified to reduce the head on the pump. However, if during normal maintenance, the pump must be repaired or replaced, it should be sized according to its new use. Restaging the well pump during normal repair or replacement would be cost-effective.

The treatment system will be designed to provide an overall removal efficiency of 98 percent. The total VOC concentration in the column effluent is estimated to be less than or equal to 16 ug/l, which is well below the current NJDEP guideline of less than or equal to 100 ug/l.

Project Costs

Estimated construction costs for the recommended treatment facilities and pipelines were developed based on the design criteria and preliminary layout and sizing of equipment described in the previous sections of this chapter. Installed costs for the packed column and the major equipment items, such as the blowers and intermediate booster pumps, are based on preliminary quotations from several manufacturers. All costs were developed in current (late 1982) dollars.

The total November 1982 construction costs for the recommended treatment facilities and pipelines are estimated as follows:

| | |
|---|---|
| Westmoreland Treatment Facility | $189,000 |
| Cadmus Place Treatment Facility | 260,000 |
| Well Nos. 23 and 24 Pipeline | 166,000 |
| Well No. 9 Pipeline | 49,000 |
| Total Current Construction Cost | $664,000 |

Detailed cost estimates for each treatment facility and pipeline are presented in Table 32.

TABLE 32

PRELIMINARY COST ESTIMATES
FOR RECOMMENDED FACILITIES

| Treatment Facility | Westmoreland Treatment Facility | Cadmus Place Treatment Facility |
|---|---|---|
| Packed Column[1] | $ 50,000 | $ 75,000 |
| Aeration Equipment[2] | 7,500 | 15,000 |
| Pumping Equipment | 16,500 | 20,000 |
| Pipe and Valves[3] | 30,000 | 40,000 |
| Building/Clearwell[4] | 45,000 | 65,000 |
| Electrical and Instrumentation | 15,000 | 10,000 |
| Sitework[5] | 25,000 | 35,000 |
| Subtotal | $189,000 | $260,000 |
| **Pipelines** | | |
| 6-inch line from Well No. 9 to Bellair Ave. | $ | $ 49,000 |
| 6-inch line from Well Nos. 23 and 24 to Westmoreland (incl. jacking under Rt. 208) | 166,000 | - |
| Subtotal | $166,000 | $ 49,000 |
| Total Current Construction Costs | $355,000 | $309,000 |

Notes:

1. Includes aluminum column, packing, column intervals, and demister mat.

2. Includes the blower, ductwork, and intake screen.

3. Includes outside and interior piping and valves.

4. Includes an insulated butler-type building with a reinforced concrete clearwell.

5. Includes such items as a fence around the facility, paved driveway, expanding the chlorinator at the Westmoreland Wellfield and drain lines.

Allowances must be made to the construction costs for contingencies, technical services and cost escalation to the mid-point construction period. Because the cost estimates presented in this report are based on preliminary designs, an allowance of 10 percent has been included for contingencies. For the purpose of estimating total project costs, an allowance of another 15 percent has been included for engineering, legal and administrative costs. A more accurate estimate of the engineering costs for design of facilities and construction administration will be made prior to the design phase of the project. The implementation plan outlined in the next section of this chapter has been used to estimate the mid-point of construction. Based on this schedule, the mid-point of construction is about September 1983, or 10 months from the date of this cost estimate. Assuming cost inflation at an average rate of 10 percent per year, an allowance of 8 percent has been used to escalate the present day costs to the mid-point of construction.

In summary, the total project cost for the recommended facilities to remove VOCs from the Borough's ground water supply is estimated as follows:

| | |
|---|---|
| Current Construction Cost | $664,000 |
| Escalation to Mid-Point of Construction (8%) | 53,200 |
| Subtotal | $717,200 |
| Allowance for Contingencies (10%) | 71,700 |
| Subtotal | $788,900 |
| Allowance for Technical Services (15%) | 118,300 |
| Total Project Cost | $907,200 |

Annual operation and maintenance costs for the recommended facilities have been developed based on the size and type of equipment selected for each treatment facility. The major operating cost item is power to operate the blowers and the intermediate booster pumps. The total annual operation and maintenance costs for the first year of operation (1983-84) of each treatment facility are summarized below:

| | Westmoreland Treatment Facility | Cadmus Place Treatment Facility |
|---|---|---|
| Power-Blower | $ 6,000 | $15,000 |
| Power-Pumps | 8,000 | 15,000 |
| Power-Misc. | 3,000 | 3,000 |
| Labor | 2,000 | 2,000 |
| Maintenance Materials | 3,000 | 4,000 |
| Totals | $22,000 | $39,000 |

Power costs are based on the estimated horsepower requirements and a unit cost for electricity of $0.11 per kilowatt hour. Labor costs were estimated based on one percent of the contruction cost, while maintenance costs were based on two percent of the construction cost. The proposed treatment facilities will not require any additional VOC monitoring than that which the Borough is currently conducting. WHICH IS ??

Project Schedule

The following is an estimated schedule for implementing the recommended treatment strategy for controlling VOC levels in the Borough's water supply system.

| | |
|---|---|
| - Complete Preliminary Design Report | December 1982 |
| - Obtain State Approval | December 1982 |
| - Initiate Final Design of Treatment Units | January 1983 |
| - Complete Final Design | May 1983 |
| - Approvals, Bid, Award and Start Construction | August 1983 |
| - Complete Construction and Start-up Facility | December 1983 |

This schedule is based on standard design, bidding and construction practices. Also, it is assumed that both treatment facilities will be designed and built at the same time. An accelerated schedule can be developed, if necessary, to meet an earlier compliance date.

An alternative schedule would involve the construction of the Cadmus Place Treatment Facility at a later date, when VOC levels rise to unacceptable levels. Also, the construction of a pipeline to connect Well No. 9 to the Cadmus Place Facility may be postponed until VOC levels in that well rise to unacceptable levels. There are several advantages associated with designing and building the treatment facilities for Cadmus Place and Well No. 9 concurrently with those facilities for the Westmoreland site. These advantages include:

1. The potential for VOC levels to rise in the Cadmus Place and Memorial Park wells and Well No. 9 is great. Also, regulations concerning the VOCs may become more stringent. As a result, treatment appears to be highly possible for these wells at some time in the future. NOT QUITE CONSISTANT WITH Pg 3-13

2. Delaying the design and construction to a later date will increase costs because of inflation.

3. Design time can be reduced because of the similarity of the Cadmus Place and Westmoreland facilities.

4. The consumer can be assured that all affected sources of water are being treated regardless of the concentration of the VOCs.

The disadvantages of proceeding with concurrent design and construction of these facilities is the treatment of water now which currently meets the NJDEP guideline of 100 ug/l for total VOCs. These advantages and disadvantages must be weighed in determining the final project schedule.

APPENDIX A

RESULTS OF GC/MC SCANS

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**INDUSTRIAL CORROSION MANAGEMENT INCORPORATED**

1152 ROUTE 10, RANDOLPH, NEW JERSEY 07869 201-584-0330

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PARAMUS, N.J.

VOLATILE ORGANICS BY PURGE AND TRAP GC/MS

*STATE CERTIFIED DRINKING WATER LABORATORY NUMBER 14116*

Report Date: July 20, 1982

SAMPLE SOURCE: Malcolm Pirnie Westmore Land Site

SAMPLE DATE: ______ TAKEN BY: ______ AT LAB DATE: 7/15/82 LAB NUMBER: 18421

*Compounds detected in parts per billion (micrograms/liter)*

A-1

| Compound | ppb | Compound | ppb |
|---|---|---|---|
| CHLOROMETHANE | | 1,2-DICHLOROPROPANE | |
| BROMOMETHANE | | t-1,3-DICHLOROPROPENE | |
| DICHLORODIFLUOROMETHANE | | TRICHLOROETHYLENE (TCE) | 55.4 |
| VINYL CHLORIDE | | DIBROMOCHLOROMETHANE | |
| CHLOROETHANE | | BENZENE | |
| METHYLENE CHLORIDE | 267.8 | DIISOPROPYL ETHER | |
| TRICHLOROFLUOROMETHANE | | 1,1,2-TRICHLOROETHANE | |
| 1,1-DICHLOROETHYLENE | 12.1 | c-1,3-DICHLOROPROPENE | |
| 1,1-DICHLOROETHANE | 6.1 | 2-CHLOROETHYLVINYL ETHER | |
| t-1,2-DICHLOROETHYLENE | 21.8 | BROMOFORM | |
| CHLOROFORM | 38.0 | 1,1,2,2-TETRACHLOROETHANE | |
| 1,2-DICHLOROETHANE | | TETRACHLOROETHYLENE (PCE) | 331.5 |
| 1,1,1-TRICHLOROETHANE | 105.3 | TOLUENE | |
| t-BUTYLMETHYL ETHER | | CHLOROBENZENE | |
| CARBON TETRACHLORIDE | | ETHYLBENZENE | |
| BROMODICHLOROMETHANE | | HEPTANE | |
| ACETONE | | XYLENE (p,m,o Total) | |

____ For the above listed volatile priority pollutants, nothing detected at 1 ppb sensitivity level.

X Other peaks detected freon 113 5 ppb

LT = Less than, GT = Greater than, ND = Not detected

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## ACID EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie Lab #18421

| | | | |
|---|---|---|---|
| 4-Chloro-3-methylphenol | LT 0.39 | ppb | ND |
| 2-Chlorophenol | LT 0.39 | ppb | ND |
| 2,4-Dichlorophenol | LT 0.39 | ppb | ND |
| 2,4-Dimethylphenol | LT 0.39 | ppb | ND |
| 2,4-Dinitrophenol | LT 0.39 | ppb | ND |
| 2-Methyl-4,6-dinitrophenol | LT 0.39 | ppb | ND |
| 2-Nitrophenol | LT 0.39 | ppb | ND |
| 4-Nitrophenol | LT 0.39 | ppb | ND |
| Pentachlorophenol | LT 0.39 | ppb | ND |
| Phenol | LT 0.39 | ppb | ND |
| 2,4,6-Trichlorophenol | LT 0.39 | ppb | ND |

LT = Less Than
ND = Not Detected

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## PESTICIDE EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie Lab #18421

| | |
|---|---|
| Aldrin | LT 0.29 ppb ND |
| a-BHC | LT 0.29 ppb ND |
| b-BHC | LT 0.29 ppb ND |
| d-BHC | LT 0.29 ppb ND |
| g-BHC | LT 0.29 ppb ND |
| Chlordane | LT 0.29 ppb ND |
| 4,4'-DDD | LT 0.29 ppb ND |
| 4,4'-DDE | LT 0.29 ppb ND |
| 4,4'-DDT | LT 0.29 ppb ND |
| Dieldrin | LT 0.29 ppb ND |
| Endosulfan I | LT 0.29 ppb ND |
| Endosulfan II | LT 0.29 ppb ND |
| Endosulfan Sulfate | LT 0.29 ppb ND |
| Endrin | LT 0.29 ppb ND |
| Endrin Aldehyde | LT 0.29 ppb ND |
| Heptachlor | LT 0.29 ppb ND |
| Heptachlor Epoxide | LT 0.29 ppb ND |
| Toxaphene | LT 0.29 ppb ND |
| PCB-1016 | LT 0.29 ppb ND |
| PCB-1221 | LT 0.29 ppb ND |
| PCB-1232 | LT 0.29 ppb ND |
| PCB-1242 | LT 0.29 ppb ND |
| PCB-1248 | LT 0.29 ppb ND |
| PCB-1254 | LT 0.29 ppb ND |
| PCB-1260 | LT 0.29 ppb ND |

LT = Less Than
ND = Not Detected

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## BASE/NEUTRAL EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie — Lab #18421

| | | | | |
|---|---|---|---|---|
| 1,3-Dichlorobenzene | LT | 0.29 | ppb | ND |
| 1,4-Dichlorobenzene | LT | 0.29 | ppb | ND |
| Hexachloroethane | LT | 0.29 | ppb | ND |
| Bis(2-chloroethyl)ether | LT | 0.29 | ppb | ND |
| 1,2-Dichlorobenzene | LT | 0.29 | ppb | ND |
| Bis(2-chloroisopropyl)ether | LT | 0.29 | ppb | ND |
| N-nitroso-di-n-propyl amine | LT | 0.29 | ppb | ND |
| Nitrobenzene | LT | 0.29 | ppb | ND |
| Hexachlorobutadiene | LT | 0.29 | ppb | ND |
| 1,2,4-Trichlorobenzene | LT | 0.29 | ppb | ND |
| Isophorone | LT | 0.29 | ppb | ND |
| Naphthalene | LT | 0.29 | ppb | ND |
| Bis(2-chloroethoxy)methane | LT | 0.29 | ppb | ND |
| Hexachlorocyclopentadiene | LT | 0.29 | ppb | ND |
| 2-Chloronaphthalene | LT | 0.29 | ppb | ND |
| Acenaphthylene | LT | 0.29 | ppb | ND |
| Acenaphthene | LT | 0.29 | ppb | ND |
| Dimethyl phthalate | LT | 0.29 | ppb | ND |
| 2,6-Dinitrotoluene | LT | 0.29 | ppb | ND |
| Fluorene | LT | 0.29 | ppb | ND |
| 4-Chlorophenyl phenyl ether | LT | 0.29 | ppb | ND |
| 2,4-Dinitrotoluene | LT | 0.29 | ppb | ND |
| 1,2-Diphenyl hydrazine* | LT | 0.29 | ppb | ND |
| Diethyl phthalate | LT | 0.29 | ppb | ND |
| N-nitrosodiphenyl amine** | LT | 0.29 | ppb | ND |
| Hexachlorobenzene | LT | 0.29 | ppb | ND |
| 4-Bromophenyl phenyl ether | LT | 0.29 | ppb | ND |
| Phenanthrene | LT | 0.29 | ppb | ND |
| Anthracene | LT | 0.29 | ppb | ND |
| Di-n-butyl phthalate | LT | 0.29 | ppb | ND |
| Fluoranthene | LT | 0.29 | ppb | ND |
| Pyrene | LT | 0.29 | ppb | ND |
| Benzidine | LT | 0.29 | ppb | ND |
| Butyl benzyl phthalate | LT | 0.29 | ppb | ND |
| Bis(2-ethylhexyl)phthalate | LT | 0.29 | ppb | ND |
| Chrysene | LT | 0.29 | ppb | ND |
| Benzo(a)anthracene | LT | 0.29 | ppb | ND |
| 3,3'-Dichlorobenzidine | LT | 0.29 | ppb | ND |
| Di-n-octyl phthalate | LT | 0.29 | ppb | ND |
| Benzo(b)fluoranthene | LT | 0.29 | ppb | ND |
| Benzo(k)fluoranthene | LT | 0.29 | ppb | ND |
| Benzo(a)pyrene | LT | 0.29 | ppb | ND |
| Indeno(1,2,3-c,d)pyrene | LT | 0.29 | ppb | ND |

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BASE/NEUTRAL EXTRACTABLES PRIORITY POLLUTANTS(continued)

Malcolm Pirnie Lab #18421

| | |
|---|---|
| Dibenzo(a,h)anthracene | LT 0.29 ppb ND |
| Benzo(g,h)perylene | LT 0.29 ppb ND |
| N-Nitrosodimethylamine | LT 0.29 ppb ND |
| Bis(chloromethyl)ether | LT 0.29 ppb ND |
| 2,3,7,8-Tetrachlorodibenzo-p-dioxin | LT 0.29 ppb ND |

LT = Less Than
ND = Not Detected
* = Detected as azobenzene
** = Detected as diphenylamine

VOLATILE ORGANICS BY PURGE AND TRAP GC/MS

# INDUSTRIAL CORROSION MANAGEMENT INCORPORATED

1152 ROUTE 10, RANDOLPH, NEW JERSEY 07869 201-584-0330

*STATE CERTIFIED DRINKING WATER LABORATORY NUMBER 14116*

RECEIVED
JUL 21 1982
MALCOLM PIRNIE, INC.
PARAMUS, N. J.

Report Date: July 20, 1982

SAMPLE SOURCE: Malcolm Pirnie Well #24

SAMPLE DATE: ______ TAKEN BY: ______ AT LAB DATE: 7/15/82 LAB NUMBER: 18420

*Compounds detected in parts per billion (micrograms/liter)*

| | | | |
|---|---|---|---|
| CHLOROMETHANE |  | 1,2-DICHLOROPROPANE |  |
| BROMOMETHANE |  | t-1,3-DICHLOROPROPENE |  |
| DICHLORODIFLUOROMETHANE |  | TRICHLOROETHYLENE (TCE) | 157.9 |
| VINYL CHLORIDE |  | DIBROMOCHLOROMETHANE |  |
| CHLOROETHANE |  | BENZENE |  |
| METHYLENE CHLORIDE | 121.9 | DIISOPROPYL ETHER |  |
| TRICHLOROFLUOROMETHANE |  | 1,1,2-TRICHLOROETHANE |  |
| 1,1-DICHLOROETHYLENE | 17.1 | c-1,3-DICHLOROPROPENE |  |
| 1,1-DICHLOROETHANE | 5.0 | 2-CHLOROETHYLVINYL ETHER |  |
| t-1,2-DICHLOROETHYLENE | 214.8 | BROMOFORM |  |
| CHLOROFORM | 173.2 | 1,1,2,2-TETRACHLOROETHANE |  |
| 1,2-DICHLOROETHANE |  | TETRACHLOROETHYLENE (PCE) | 3.0 |
| 1,1,1-TRICHLOROETHANE | 107.8 | TOLUENE |  |
| t-BUTYLMETHYL ETHER |  | CHLOROBENZENE |  |
| CARBON TETRACHLORIDE | 79.1 | ETHYLBENZENE |  |
| BROMODICHLOROMETHANE | 1.6 | HEPTANE |  |
| ACETONE |  | XYLENE (p,m,o Total) |  |

_____ For the above listed volatile priority pollutants, nothing detected at 1 ppb sensitivity level.

_____ Other peaks detected ______

LT = Less than, GT = Greater than, ND = Not detected

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## ACID EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie — Lab #18420

| | | | | |
|---|---|---|---|---|
| 4-Chloro-3-methylphenol | LT | 0.46 | ppb | ND |
| 2-Chlorophenol | LT | 0.46 | ppb | ND |
| 2,4-Dichlorophenol | LT | 0.46 | ppb | ND |
| 2,4-Dimethylphenol | LT | 0.46 | ppb | ND |
| 2,4-Dinitrophenol | LT | 0.46 | ppb | ND |
| 2-Methyl-4,6-dinitrophenol | LT | 0.46 | ppb | ND |
| 2-Nitrophenol | LT | 0.46 | ppb | ND |
| 4-Nitrophenol | LT | 0.46 | ppb | ND |
| Pentachlorophenol | LT | 0.46 | ppb | ND |
| Phenol | LT | 0.46 | ppb | ND |
| 2,4,6-Trichlorophenol | LT | 0.46 | ppb | ND |

LT = Less Than
ND = Not Detected

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# PESTICIDE EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie Lab #18420

| | |
|---|---|
| Aldrin | LT 0.37 ppb ND |
| a-BHC | LT 0.37 ppb ND |
| b-BHC | LT 0.37 ppb ND |
| d-BHC | LT 0.37 ppb ND |
| g-BHC | LT 0.37 ppb ND |
| Chlordane | LT 0.37 ppb ND |
| 4,4'-DDD | LT 0.37 ppb ND |
| 4,4'-DDE | LT 0.37 ppb ND |
| 4,4'-DDT | LT 0.37 ppb ND |
| Dieldrin | LT 0.37 ppb ND |
| Endosulfan I | LT 0.37 ppb ND |
| Endosulfan II | LT 0.37 ppb ND |
| Endosulfan Sulfate | LT 0.37 ppb ND |
| Endrin | LT 0.37 ppb ND |
| Endrin Aldehyde | LT 0.37 ppb ND |
| Heptachlor | LT 0.37 ppb ND |
| Heptachlor Epoxide | LT 0.37 ppb ND |
| Toxaphene | LT 0.37 ppb ND |
| PCB-1016 | LT 0.37 ppb ND |
| PCB-1221 | LT 0.37 ppb ND |
| PCB-1232 | LT 0.37 ppb ND |
| PCB-1242 | LT 0.37 ppb ND |
| PCB-1248 | LT 0.37 ppb ND |
| PCB-1254 | LT 0.37 ppb ND |
| PCB-1260 | LT 0.37 ppb ND |

LT = Less Than
ND = Not Detected

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BASE/NEUTRAL EXTRACTABLES PRIORITY POLLUTANTS

Malcolm Pirnie Lab #18420

| | | | |
|---|---|---|---|
| 1,3-Dichlorobenzene | LT 0.37 | ppb | ND |
| 1,4-Dichlorobenzene | LT 0.37 | ppb | ND |
| Hexachloroethane | LT 0.37 | ppb | ND |
| Bis(2-chloroethyl)ether | LT 0.37 | ppb | ND |
| 1,2-Dichlorobenzene | LT 0.37 | ppb | ND |
| Bis(2-chloroisopropyl)ether | LT 0.37 | ppb | ND |
| N-nitroso-di-n-propyl amine | LT 0.37 | ppb | ND |
| Nitrobenzene | LT 0.37 | ppb | ND |
| Hexachlorobutadiene | LT 0.37 | ppb | ND |
| 1,2,4-Trichlorobenzene | LT 0.37 | ppb | ND |
| Isophorone | LT 0.37 | ppb | ND |
| Naphthalene | LT 0.37 | ppb | ND |
| Bis(2-chloroethoxy)methane | LT 0.37 | ppb | ND |
| Hexachlorocyclopentadiene | LT 0.37 | ppb | ND |
| 2-Chloronaphthalene | LT 0.3- | ppb | ND |
| Acenaphthylene | LT 0.37 | ppb | ND |
| Acenaphthene | LT 0.37 | ppb | ND |
| Dimethyl phthalate | LT 0.37 | ppb | ND |
| 2,6-Dinitrotoluene | LT 0.37 | ppb | ND |
| Fluorene | LT 0.37 | ppb | ND |
| 4-Chlorophenyl phenyl ether | LT 0.37 | ppb | ND |
| 2,4-Dinitrotoluene | LT 0.37 | ppb | ND |
| 1,2-Diphenyl hydrazine* | LT 0.37 | ppb | ND |
| Diethyl phthalate | LT 0.37 | ppb | ND |
| N-nitrosodiphenyl amine** | LT 0.37 | ppb | ND |
| Hexachlorobenzene | LT 0.37 | ppb | ND |
| 4-Bromophenyl phenyl ether | LT 0.37 | ppb | ND |
| Phenanthrene | LT 0.37 | ppb | ND |
| Anthracene | LT 0.37 | ppb | ND |
| Di-n-butyl phthalate | LT 0.37 | ppb | ND |
| Fluoranthene | LT 0.37 | ppb | ND |
| Pyrene | LT 0.37 | ppb | ND |
| Benzidine | LT 0.37 | ppb | ND |
| Butyl benzyl phthalate | LT 0.37 | ppb | ND |
| Bis(2-ethylhexyl)phthalate | LT 0.37 | ppb | ND |
| Chrysene | LT 0.37 | ppb | ND |
| Benzo(a)anthracene | LT 0.37 | ppb | ND |
| 3,3'-Dichlorobenzidine | LT 0.37 | ppb | ND |
| Di-n-octyl phthalate | LT 0.37 | ppb | ND |
| Benzo(b)fluoranthene | LT 0.37 | ppb | ND |
| Benzo(k)fluoranthene | LT 0.37 | ppb | ND |
| Benzo(a)pyrene | LT 0.37 | ppb | ND |
| Indeno(1,2,3-c,d)pyrene | LT 0.37 | ppb | ND |

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BASE/NEUTRAL EXTRACTABLES PRIORITY POLLUTANTS(continued)

Malcolm Pirnie Lab #18420

| | | | | |
|---|---|---|---|---|
| Dibenzo(a,h)anthracene | LT | 0.37 | ppb | ND |
| Benzo(g,h)perylene | LT | 0.37 | ppb | ND |
| N-Nitrosodimethylamine | LT | 0.37 | ppb | ND |
| Bis(chloromethyl)ether | LT | 0.37 | ppb | ND |
| 2,3,7,8-Tetrachlorodibenzo-p-dioxin | LT | 0.37 | ppb | ND |

LT = Less Than
ND = Not Detected
* = Detected as azobenzene
** = Detected as diphenylamine

# APPENDIX B

## RESULTS OF PACKED COLUMN AERATION TREATABILITY TESTS

TABLE B-1

PILOT PACKED COLUMN TEST RESULTS
CARBON TETRACHLORIDE

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Carbon Tetrachloride (ug/l) Influent | Carbon Tetrachloride (ug/l) Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Well No. 24 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 48 | 5.2 | 89 |
| 2 | 15 | 160 | 80:1 | 39 | 2.3 | 94 |
| 3 | 27 | 72 | 20:1 | 50 | 6.2 | 88 |
| 4 | 20 | 134 | 50:1 | 55 | 4.1 | 94 |
| 5 | 24 | 89 | 30:1 | 55 | 5.6 | 90 |

TABLE B-2

PILOT PACKED COLUMN TEST RESULTS
TRICHLOROETHYLENE REMOVAL

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | TCE (ug/l) Influent | TCE (ug/l) Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| **Westmoreland Field Wells — Data for 2-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 13 | 0.1 | 99 |
| 2 | 17 | 114 | 50:1 | 15 | 0.3 | 98 |
| 3 | 23 | 77 | 25:1 | 15 | 0.7 | 95 |
| 4 | 28 | 37 | 10:1 | 15 | 2.0 | 87 |
| 5 | 28 | 160 | 43:1 | 31 | 0.6 | 98 |
| 6 | 32 | 160 | 37:1 | 37 | 1.4 | 96 |
| 7 | 24 | 96 | 30:1 | 35 | 1.3 | 96 |
| 8 | 21 | 84 | 30:1 | 28 | 1.5 | 95 |
| 9 | 16 | 43 | 20:1 | 32 | 1.4 | 96 |
| 10 | 14 | 32 | 17:1 | 33 | 2.0 | 94 |
| **Data for 1-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 16 | <1 | >94 |
| 2 | 17 | 114 | 50:1 | 13 | <1 | >92 |
| 3 | 23 | 77 | 25:1 | 13 | 1.7 | 87 |
| 4 | 28 | 37 | 10:1 | 6 | 3 | 50 |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 15 | 160 | 80:1 | 21 | <1 | >95 |
| 2 | 17 | 114 | 50:1 | 21 | <1 | >95 |
| 3 | 23 | 77 | 25:1 | 21 | 1.5 | 93 |
| 4 | 28 | 56 | 15:1 | 21 | 2.0 | 90 |
| 5 | 15 | 160 | 80:1 | 67 | 2.7 | 96 |
| 6 | 17 | 114 | 50:1 | 67 | 5.0 | 93 |
| 7 | 23 | 77 | 25:1 | 67 | 12 | 82 |
| 8 | 28 | 56 | 15:1 | 67 | 16 | 76 |
| **Cadmus - Memorial Wells — Data for 2-inch Tri-packs** | | | | | | |
| 1 | 32 | 160 | 37:1 | 13.1 | 0.1 | 99 |
| 2 | 29 | 160 | 41:1 | 13.1 | 0.5 | 96 |
| 3 | 27 | 72 | 20:1 | 2.1 | 0.5 | 76 |
| 4 | 22 | 118 | 40:1 | 2.1 | 0.2 | 90 |
| 5 | 20 | 134 | 50:1 | 2.0 | 0.2 | 90 |
| 6 | 17 | 148 | 65:1 | 2.0 | 0.1 | 95 |
| 7 | 15 | 160 | 80:1 | 2.1 | 0.1 | 95 |

TABLE B-2

PILOT PACKED COLUMN TEST RESULTS
TRICHLOROETHYLENE REMOVAL (Cont'd)

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | TCE (ug/l) Influent | TCE (ug/l) Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Well No. 24 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 87 | 16 | 82 |
| 2 | 15 | 160 | 80:1 | 77 | 5.6 | 93 |
| 3 | 27 | 72 | 20:1 | 96 | 10 | 90 |
| 4 | 20 | 134 | 50:1 | 84 | 4.8 | 94 |
| 5 | 24 | 89 | 30:1 | 92 | 20 | 78 |
| Well No. 9 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 7.1 | 3.2 | 55 |
| 2 | 29 | 160 | 41:1 | 7.1 | 2.1 | 70 |
| 3 | 27 | 72 | 20:1 | 13.4 | 4 | 70 |
| 4 | 24 | 96 | 30:1 | 13.4 | 5 | 63 |

TABLE B-3

PILOT PACKED COLUMN TEST RESULTS
TETRACHLOROETHYLENE REMOVAL

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | PCE (ug/l) Influent | PCE (ug/l) Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| **Westmoreland Field Wells Data for 2-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 31 | 0.3 | 99 |
| 2 | 17 | 114 | 50:1 | 29 | 0.8 | 97 |
| 3 | 23 | 77 | 25:1 | 31 | 1.4 | 95 |
| 4 | 28 | 37 | 10:1 | 32 | 3.0 | 91 |
| 5 | 28 | 160 | 43:1 | 154 | 5.0 | 97 |
| 6 | 32 | 160 | 37:1 | 185 | 10.0 | 95 |
| 7 | 24 | 96 | 30:1 | 166 | 8.0 | 95 |
| 8 | 21 | 84 | 30:1 | 158 | 7.0 | 96 |
| 9 | 16 | 43 | 20:1 | 143 | 7.0 | 95 |
| 10 | 14 | 32 | 17:1 | 142 | 8.0 | 94 |
| **Data for 1 inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 61 | 1.0 | 98 |
| 2 | 17 | 114 | 50:1 | 27 | <1 | >96 |
| 3 | 23 | 77 | 25:1 | 29 | 4.0 | 86 |
| 4 | 28 | 37 | 10:1 | 15 | 6.0 | 60 |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 15 | 160 | 80:1 | 36 | 1.6 | 96 |
| 2 | 17 | 114 | 50:1 | 36 | 1.5 | 96 |
| 3 | 23 | 77 | 25:1 | 36 | 2.8 | 92 |
| 4 | 28 | 56 | 15:1 | 36 | 3.5 | 90 |
| 5 | 15 | 160 | 80:1 | 314 | 18 | 94 |
| 6 | 17 | 114 | 50:1 | 314 | 24 | 92 |
| 7 | 23 | 77 | 25:1 | 314 | 50 | 84 |
| 8 | 28 | 56 | 15:1 | 455 | 58 | 87 |
| **Cadmus - Memorial Combined Wells Data for 2 inch Tri-packs** | | | | | | |
| 1 | 32 | 160 | 37:1 | 9.7 | - | - |
| 2 | 29 | 160 | 41:1 | 9.7 | 3.2 | 67 |
| 3 | 27 | 72 | 20:1 | 9.7 | 3.3 | 68 |
| 4 | 22 | 118 | 40:1 | 9.7 | 2.5 | 74 |
| 5 | 20 | 134 | 50:1 | 10.6 | 2.1 | 80 |
| 6 | 17 | 148 | 65:1 | 10.6 | 1.0 | 91 |
| 7 | 15 | 160 | 80:1 | 11.0 | 1.1 | 90 |

TABLE B-3

PILOT PACKED COLUMN TEST RESULTS
TETRACHLOROETHYLENE REMOVAL (Cont'd)

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | TCE (ug/l) Influent | TCE (ug/l) Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Well No. 24 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 3.0 | <1 | >67 |
| 2 | 15 | 160 | 80:1 | 2.2 | <1 | >55 |
| 3 | 27 | 72 | 20:1 | 2.4 | <1 | >58 |
| 4 | 20 | 134 | 50:1 | 2.3 | <1 | >57 |
| 5 | 24 | 89 | 30:1 | 2.2 | <1 | >55 |
| Well No. 9 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 3.5 | 2.7 | 23 |
| 2 | 29 | 160 | 41:1 | 3.5 | 0.9 | 74 |
| 3 | 27 | 72 | 20:1 | 6.0 | <1 | >83 |
| 4 | 24 | 96 | 30:1 | 6.0 | <1 | >83 |

TABLE B-4

PILOT PACKED COLUMN TEST RESULTS
1,1,1-TRICHLOROETHANE

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | 1,1,1-Trichloroethane (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| **Westmoreland Field Wells Data for 2-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 82 | 2.0 | 98 |
| 2 | 17 | 114 | 50:1 | 75 | 4.0 | 95 |
| 3 | 23 | 77 | 25:1 | 84 | 7.0 | 92 |
| 4 | 28 | 37 | 10:1 | 84 | 12 | 86 |
| 5 | 28 | 160 | 43:1 | 94 | 3.0 | 97 |
| 6 | 32 | 160 | 37:1 | 98 | 5.0 | 95 |
| 7 | 24 | 96 | 30:1 | 104 | 5.0 | 95 |
| 8 | 21 | 84 | 30:1 | 96 | 6.0 | 94 |
| 9 | 16 | 43 | 20:1 | 98 | 5.0 | 95 |
| 10 | 14 | 32 | 17:1 | 108 | 6.0 | 94 |
| **Data for 1 inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 81 | 2.0 | 98 |
| 2 | 17 | 114 | 50:1 | 73 | 4.0 | 95 |
| 3 | 23 | 77 | 25:1 | 77 | 6.0 | 92 |
| 4 | 28 | 37 | 10:1 | 59 | 14 | 76 |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 15 | 160 | 80:1 | 77 | 4.5 | 94 |
| 2 | 17 | 114 | 50:1 | 77 | 4.8 | 94 |
| 3 | 23 | 77 | 25:1 | 77 | 8.0 | 90 |
| 4 | 28 | 56 | 15:1 | 77 | 11 | 86 |
| 5 | 15 | 160 | 80:1 | 131 | 5.8 | 96 |
| 6 | 17 | 114 | 50:1 | 131 | 8.0 | 94 |
| 7 | 23 | 77 | 25:1 | 131 | 9.0 | 93 |
| 8 | 28 | 56 | 15:1 | 178 | 20 | 89 |
| **Well No. 24 Data for 2-inch Tri-packs** | | | | | | |
| 1 | 32 | 160 | 37:1 | 115 | 12 | 90 |
| 2 | 15 | 160 | 80:1 | 97 | 4.8 | 95 |
| 3 | 27 | 72 | 20:1 | 134 | 15 | 89 |
| 4 | 20 | 134 | 50:1 | 132 | 7.0 | 95 |
| 5 | 24 | 89 | 30:1 | 106 | 15 | 86 |

TABLE B-4

PILOT PACKED COLUMN TEST RESULTS
1,1,1-TRICHLOROETHANE (Cont'd)

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | 1,1,1-Trichloroethane (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Well No. 9 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 2.9 | 1.2 | 59 |
| 2 | 29 | 160 | 41:1 | 2.9 | 0.8 | 72 |
| 3 | 27 | 72 | 20:1 | 5.0 | 5.0 | 0 |
| 4 | 24 | 96 | 30:1 | 5.0 | 6.0 | 0 |

TABLE B-5

PILOT PACKED COLUMN TEST RESULTS
CHLOROFORM

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Chloroform (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| **Westmoreland Field Wells** | | | | | | |
| **Data for 2-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 50 | 45 | 10 |
| 2 | 17 | 114 | 50:1 | 13 | 2.0 | 85 |
| 3 | 23 | 77 | 25:1 | 15 | 4.0 | 73 |
| 4 | 28 | 37 | 10:1 | 12 | 7.0 | 42 |
| 5 | 28 | 160 | 43:1 | 23 | 0.5 | 98 |
| 6 | 32 | 160 | 37:1 | 26 | 1.1 | 96 |
| 7 | 24 | 96 | 30:1 | 28 | 0.6 | 98 |
| 8 | 21 | 84 | 30:1 | 14 | 2.0 | 86 |
| 9 | 16 | 43 | 20:1 | 25 | 0.4 | 98 |
| 10 | 14 | 32 | 17:1 | 21 | 2.0 | 90 |
| **Data for 1 inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 18 | <1 | >94 |
| 2 | 17 | 114 | 50:1 | 27 | <1 | >96 |
| 3 | 23 | 77 | 25:1 | 31 | 3 | 90 |
| 4 | 28 | 37 | 10:1 | 106 | 3 | 97 |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 15 | 160 | 80:1 | 8.0 | <1 | >88 |
| 2 | 17 | 114 | 50:1 | 8.0 | <1 | >88 |
| 3 | 23 | 77 | 25:1 | 8.0 | 1.4 | 83 |
| 4 | 28 | 56 | 15:1 | 8.0 | 2 | 75 |
| 5 | 15 | 160 | 80:1 | 25 | <1 | >96 |
| 6 | 17 | 114 | 50:1 | 25 | 4 | 84 |
| 7 | 23 | 77 | 25:1 | 25 | 5 | 80 |
| 8 | 28 | 56 | 15:1 | 52 | 7 | 87 |
| **Well No. 24** | | | | | | |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 32 | 160 | 37:1 | 120 | 18 | 85 |
| 2 | 15 | 160 | 80:1 | 88 | 6.6 | 93 |
| 3 | 27 | 72 | 20:1 | 91 | 23 | 75 |
| 4 | 20 | 134 | 50:1 | 92 | 9.1 | 90 |
| 5 | 24 | 89 | 30:1 | 120 | 19 | 84 |

TABLE B-5

PILOT PACKED COLUMN TEST RESULTS
CHLOROFORM (Cont'd)

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Chloroform (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Well No. 9 | | | | | | |
| Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 7.0 | 4.5 | 36 |
| 2 | 29 | 160 | 41:1 | 7.0 | <1 | >86 |
| 3 | 27 | 72 | 20:1 | 13.7 | 4.5 | 67 |
| 4 | 24 | 96 | 30:1 | 13.7 | 5.5 | 60 |

TABLE B-6

PILOT PACKED COLUMN TEST RESULTS
1,1-DICHLOROETHANE

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | 1,1-Dichloroethane (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| Westmoreland Field Wells Data for 2-inch Tellerettes | | | | | | |
| 1 | 12 | 160 | 100:1 | 6.0 | <1 | >83 |
| 2 | 17 | 114 | 50:1 | 3.0 | >1 | >67 |
| 3 | 23 | 77 | 25:1 | 6.0 | <1 | >83 |
| 4 | 28 | 37 | 10:1 | 4.0 | <1 | >75 |
| 5 | 28 | 160 | 43:1 | 5.0 | <1 | >80 |
| 6 | 32 | 160 | 37:1 | 5.0 | <1 | >80 |
| 7 | 24 | 96 | 30:1 | 6.0 | <1 | >83 |
| 8 | 21 | 84 | 30:1 | 7.0 | <1 | >86 |
| 9 | 16 | 43 | 20:1 | 8.0 | <1 | >88 |
| 10 | 14 | 32 | 17:1 | 10 | <1 | >90 |
| Data for 1-inch Tellerettes | | | | | | |
| 1 | 12 | 160 | 100:1 | 6.0 | <1 | <83 |
| 2 | 17 | 114 | 50:1 | 5.0 | <1 | >80 |
| 3 | 23 | 77 | 25:1 | 6.0 | <1 | >83 |
| 4 | 28 | 37 | 10:1 | 4.0 | <1 | >75 |
| Data for 2-inch Tri-packs | | | | | | |
| 1 | 15 | 160 | 80:1 | 4.0 | <1 | >75 |
| 2 | 17 | 114 | 50:1 | 4.0 | <1 | >75 |
| 3 | 23 | 77 | 25:1 | 4.0 | - | >75 |
| 4 | 28 | 56 | 15:1 | 4.0 | <1 | >75 |
| 5 | 15 | 160 | 80:1 | 5.0 | <1 | >80 |
| 6 | 17 | 114 | 50:1 | 5.0 | <1 | >80 |
| 7 | 23 | 77 | 25:1 | 5.0 | 1.1 | 78 |
| 8 | 28 | 56 | 15:1 | 6.0 | <1 | >83 |
| Well No. 24 Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 8.2 | <1 | >88 |
| 2 | 15 | 160 | 80:1 | 4.6 | <1 | >78 |
| 3 | 27 | 72 | 20:1 | 4.7 | 0.6 | 87 |
| 4 | 20 | 134 | 50:1 | 4.9 | <1 | >80 |
| 5 | 24 | 89 | 30:1 | 3.8 | <1 | >74 |

TABLE B-7

PILOT PACKED COLUMN TEST RESULTS
1,1-DICHLOROETHYLENE

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | 1,1-Dichloroethylene (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| **Westmoreland Combined Wells Data for 2-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 8 | <1 | >88 |
| 2 | 17 | 114 | 50:1 | 11 | <1 | >91 |
| 3 | 23 | 77 | 25:1 | 12 | <1 | >92 |
| 4 | 28 | 37 | 10:1 | 19 | <1 | >95 |
| 5 | 28 | 160 | 43:1 | 23 | <1 | >96 |
| 6 | 32 | 160 | 37:1 | 19 | <1 | >95 |
| 7 | 24 | 96 | 30:1 | 27 | <1 | >96 |
| 8 | 21 | 84 | 30:1 | 43 | <1 | >98 |
| 9 | 16 | 43 | 20:1 | 28 | <1 | >96 |
| 10 | 14 | 32 | 17:1 | 27 | <1 | >96 |
| **Data for 1-inch Tellerettes** | | | | | | |
| 1 | 12 | 160 | 100:1 | 20 | <1 | >95 |
| 2 | 17 | 114 | 50:1 | 17 | <1 | >94 |
| 3 | 23 | 77 | 25:1 | 32 | <1 | >97 |
| 4 | 28 | 37 | 10:1 | 20 | <1 | >95 |
| **Data for 2-inch Tri-packs** | | | | | | |
| 1 | 15 | 160 | 80:1 | 13 | <1 | >92 |
| 2 | 17 | 114 | 50:1 | 13 | <1 | >92 |
| 3 | 23 | 77 | 25:1 | 13 | <1 | >92 |
| 4 | 28 | 56 | 15:1 | 13 | <1 | >92 |
| 5 | 15 | 160 | 80:1 | 5 | <1 | >80 |
| 6 | 17 | 114 | 50:1 | 5 | <1 | >80 |
| 7 | 23 | 77 | 25:1 | 5 | 1.2 | 76 |
| 8 | 28 | 56 | 15:1 | 11 | 1.2 | 89 |

TABLE B-8

PILOT PACKED COLUMN TEST RESULTS
TRANS-1,2-DICHLOROETHYLENE

| Run No. | Water Flowrate (gpm) | Air Flowrate (cfm) | Air: Water Ratio | Trans-1,2-Dichloroethylene (ug/l) Influent | Effluent | Percent Removal |
|---|---|---|---|---|---|---|
| George Street Well No. 9 Data for 2-inch Tripacks | | | | | | |
| 1 | 32 | 160 | 100:1 | 3.7 | 1.9 | 49 |
| 2 | 29 | 160 | 41:1 | 3.7 | 0.8 | 78 |
| 3 | 27 | 72 | 20:1 | 6.6 | 1.2 | 82 |
| 4 | 24 | 96 | 30:1 | 6.6 | 1.1 | 83 |
| Cadmus-Memorial Wells Data for 2-inch Tri-packs | | | | | | |
| 1 | 32 | 160 | 37:1 | 10.5 | 0.9 | 91.4 |
| 2 | 29 | 160 | 41:1 | 10.5 | 2.5 | 76.2 |
| 3 | 27 | 72 | 20:1 | 11.1 | 2.7 | 75.7 |
| 4 | 22 | 118 | 40:1 | 11.1 | 1.8 | 83.8 |
| 5 | 20 | 134 | 50:1 | 8.0 | 1.8 | 77.5 |
| 6 | 17 | 148 | 65:1 | 8.0 | 0.8 | 90.0 |
| 7 | 15 | 160 | 80:1 | 8.5 | 0.7 | 91.8 |